DISCOVERY

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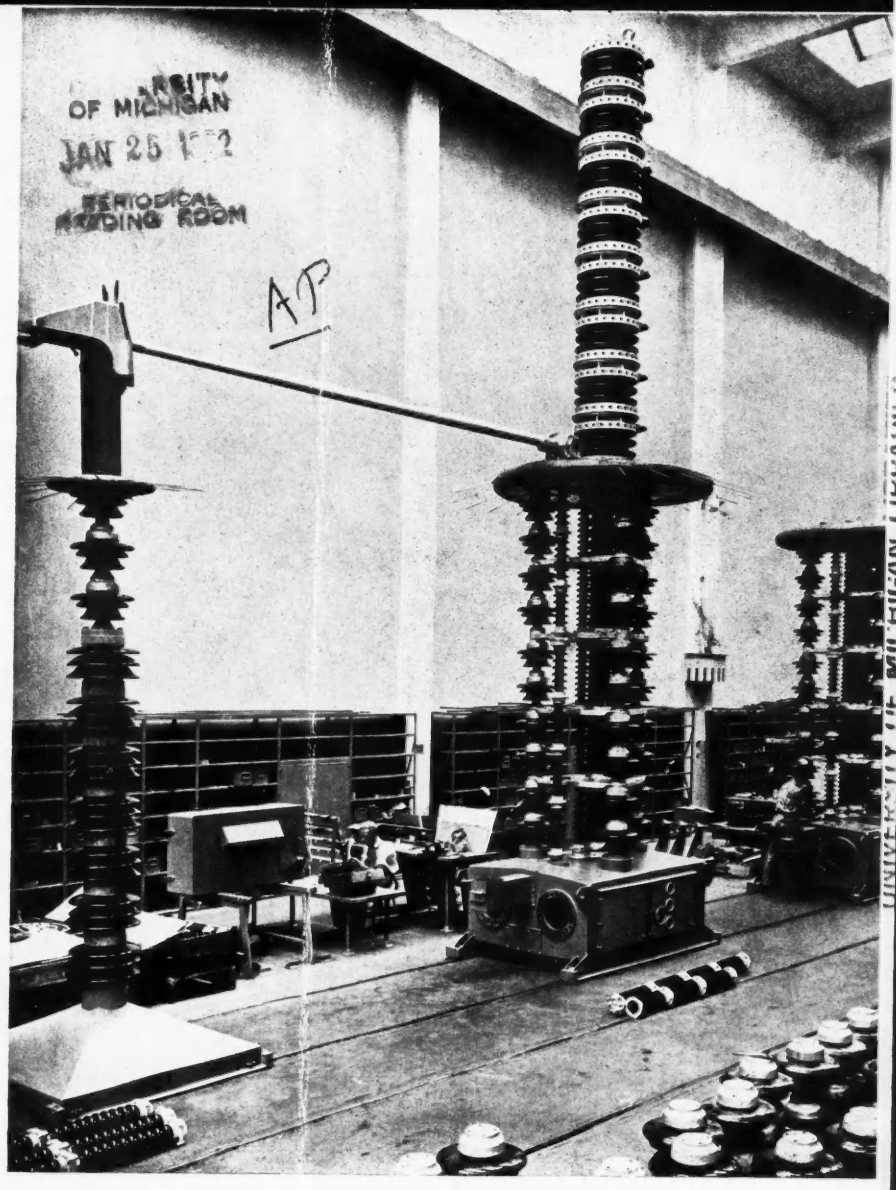

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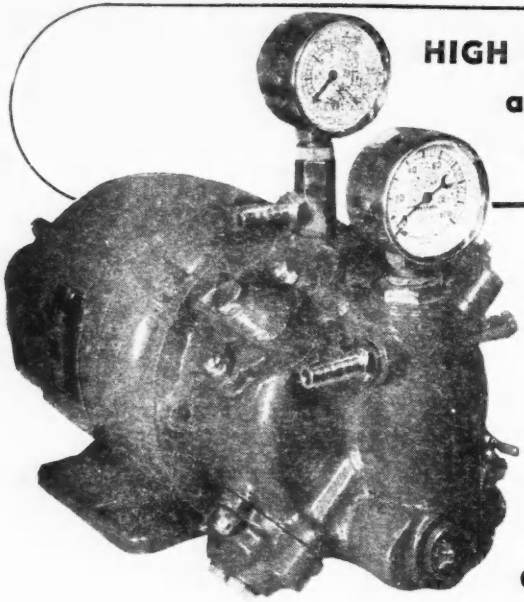

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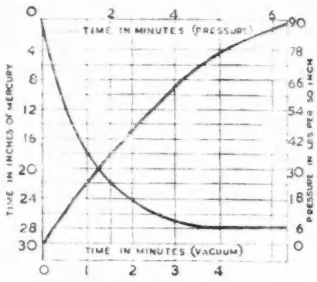

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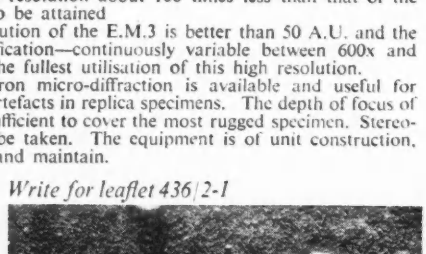

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DISCOVERY

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The Progress of Science

Part-time Technical Education

A LONG HISTORICAL PROCESS accounts for the strength of the British caste system, and its rigidity. It is still largely true to say that the average Englishman dearly loves a Lord, while a similar snobbery exists that is expressed in an uncritical respect for the 'letters' which a man can put after his name. While it is not impossible for a person endowed with talent and inflexible pertinacity to work his way out of one caste into another caste with higher social status, there is no doubt that in a large number of cases a person who attempts to make such a transfer through part-time study—by attending evening classes, for example—may undergo mental strain and even suffering which is calculated to undermine the feeling of pride which should accompany the successful attainment of his immediate objective.

Evening classes provide a means for obtaining vocational training, but they can be exhausting to the student. This is proved by the high proportion of students who fail to finish their evening courses. Moreover, the length of evening courses in technical subjects has become excessive, and there is no sign of any relief in this respect. The latest addition to the list of such courses is a part-time course in chemical engineering qualifying for a Higher National Certificate, which when followed by one year's 'endorsement' would allow the successful candidate to be exempted from certain papers in the examination of the Institution of Chemical Engineers.*

In the evening schools there are two main streams. One stream leads to an external degree of the University of London, the other to the National Certificate. The first qualification is more highly prized because the student can then put the letters 'B.Sc.' after his name. But there was, until recently, the obstacle that matriculation was an essential preliminary. For those who had not achieved that standard in such subjects as English and languages, the National Certificates awarded jointly by the Ministry of Education and the appropriate professional body afforded the possibility of climbing to professional status. In either case, the reward was often that of achievement without any corresponding material gain.

The reasons for this are complicated, and more study is needed to distinguish facts from impressions. Industrialists often say that the courses last so long that students are worn out by the time they reach the end, and that qualities other than purely academic qualities tend to suffer in the hard grind of studying after a hard day's work, a process which may result in a competent but colourless technician. The man who has taken his degree by evening classes is often in a worse shape than the National Certificate man. This is partly explained by the more arduous nature of the degree course, and another factor that is involved is the resentment which the successful student may feel if his degree is not rewarded by immediate promotion or financial advancement. The student's resentment is thoroughly justified if no recognition of his proven merit is made by his employer, and if it is obvious that the higher positions in his firm are reserved exclusively for men who obtained their degrees by full-time university work. (The injustice would then be a double injustice, for there can be no doubt that it is mentally far less exhausting to graduate through a full-time course than through a part-time course.) The National Certificate holder is generally more settled in his outlook, and is more ready to accept steady but gradual advancement. There are complaints, however, from holders of Higher National Certificates who meet difficulties when they attempt to obtain professional recognition. The student of the proposed chemical engineering course, for instance, will have to do an extra year after taking the certificate examination before he can apply to the Institution of Chemical Engineers to be exempted from parts of their professional examination. With the most favourable allowance, he would be still left with the formidable 'Home Paper' set by that body. That is a paper which takes three months to complete, the candidate having to carry out a design problem involving a search of scientific literature, the working out of a process from the chemical aspects and the engineering design of all the equipment required to realise it. Obviously, therefore, the obtaining of this particular Higher National Certificate is

* "Scheme for a Part Time Course", published by The Institution of Chemical Engineers, 56 Victoria Street, London, S.W.1.

no guarantee that the student will eventually obtain the professional qualification he desires; though it is, of course, a big step in that direction.

It is high time for all the various auxiliary routes leading to technical qualifications to be reviewed. What is needed is information about the numbers of students enrolling, and their reasons (a sample survey could obtain this information), together with a record of those who fall by the wayside, and of those who complete their courses, and at what sort of age and with what subsequent benefit to their career. Such a survey could help to clear up the confusion which obscures the whole picture of higher technological education; it could also indicate what reforms could be made to liberalise the external degree and enhance the status of the National Certificate.

It can be argued that what is required is a more thoroughgoing reconstruction of our system of technological education, if British industry is to obtain the scientists *and* technologists *and* technicians which it needs. An alternative system is indicated in the report on "Universities and Industry" which has just been published.* A team led by Dr. P. Dunsheath visited a number of leading American universities and technical institutions in order to study the ways in which U.S. industry benefits from the universities and vice versa, and their report shows that the Americans rely less on part-time study than is the case in Britain. (Actually part-time study does exist in America, in what may be described as an 'upside-down' form; there are students who work their way through college, by doing jobs in the evening or in their vacations, the money from which meets or helps to meet the college fees, etc. The outstanding difference is that they do their work *after* their study; in Britain the part-time student usually does his study after he has already done a day's work.)

The team recommends that industry should:

1. recruit a larger proportion of students who have studied full-time,
2. give them scope in the organisation to benefit from their training,
3. encourage specialists on its staff to place their knowledge at the disposal of universities,
4. release staff for higher education.

This is the right kind of approach if Britain is to find a satisfactory solution of this particular set of problems. The report deserves close consideration, and one's only regret is that it should have paid more attention to those differences in practice between the two countries which point the way to improvements worth introducing into Britain. It does, however, underline certain special features of the American system which demand examination here, for they seem to be capable of contributing to the solution of British productivity problems. Thus we find that the practice in America runs contrary to the view put forward at the British Institute of Management's conference in mid-November; the report points out that in the U.S.A. relatively few arts graduates, apart from those who have majored in business administration, find employment in industry. (The British conference favoured the arts graduate against all others.) The report also draws attention to the fact that chemical engineering has developed much more in America than here. In 1949–50, for instance, 4529 first degrees in this subject were granted, and many Americans believe that the availability of well-trained men in such numbers is one of the reasons why American industry has progressed so rapidly in recent years.

* "Universities and Industry", published by the Anglo-American Productivity Council, 21 Tothill Street, London, S.W.1.

Revolution in Optics

TWENTY or so years ago optics seemed to be in the doldrums. The student learned his instruments and his equations, and that was that. Optical research had only an academic interest, and was apparently unrelated to practical science. Then something happened, and recent years have witnessed a succession of new or vastly improved instrumental devices of immense importance, not only in astronomy and biology but also in physics and metallurgy. No one who reads about science can have remained unaware of the Schmidt camera and the phase-contrast microscope, and of the many other devices and improvements, such as the blooming of lenses, not forgetting the electron microscope. (It may be objected that this instrument belongs to electronics rather than optics; technologically, it is an electronic instrument, but its ultimate use is always for the visual examination of fine detail—functionally it is a microscope.)

So much has been achieved in the design of optical instruments in recent years that an international conference on this topic became desirable, and was held in London in July 1950. Its transactions have now been published as a book, entitled *Optical Instruments: Proceedings of the London Conference*, 1950 (London, Chapman & Hall, 264 pp., 42*s*.).

It may be wondered how this fairly sudden resurgence of activity came about. The answer, as is so often the case, is to be found in the work of a few exceptional individuals, who gave a new fillip to instrumental design. The two outstanding men were Bernhard Schmidt and Professor Zernicke. There is nothing invidious about this selection; the experts are all in complete agreement about it. Thus we find that Professor Zernicke received this tribute from Sir Thomas Merton, who presided over the conference: "I think that some twenty-five years ago microscopy was in a period of consolidation—perhaps a trifle dull—and without any sign that anything important was in the offing. Now the whole position is changed and I think that we owe the inception of the great activity which obtains in this field of optics in part to the stimulating work of Prof. Zernicke."

Professor Zernicke, who works at Groningen in Holland, is a savant who is as much at home with Bessel functions as with lenses. Bernhard Schmidt (who died in 1935) was a quite different kind of scientist. He was a craftsman, who made mirrors for telescopes; his skill, as Dr. E. H. Linfoot reminds us in the present volume, was superlative. In 1926 he joined the Bergedorf Observatory, near Hamburg, and from the time of his arrival there he was preoccupied with one of the problems involved in the design of better reflecting telescopes. In 1929 he solved his problem and the first model of his new telescope—usually called the Schmidt 'camera'—was put into operation a year later.

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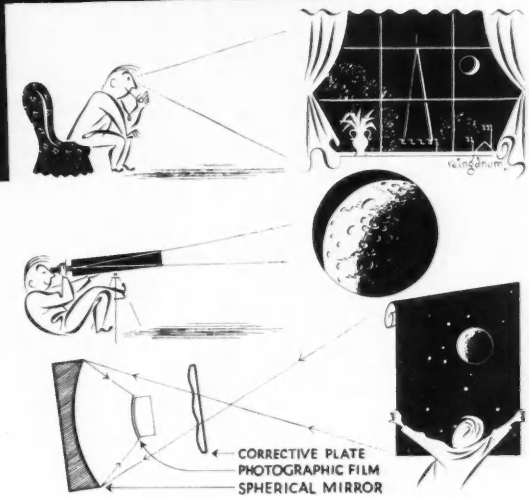
(*Right*) tiers of camera the orc Schmid



(*Above*)—The Palomar Schmidt, 'scout' for the 200-in. telescope, has a 72-in. mirror and 48-in. correcting plate. It is a wide-angle telescope capable of photographing very large sectors of sky with perfect clarity, whereas the 200-in. Palomar telescope has a narrow angle (about half a degree) but can record faint stars at very great distances. The Palomar astronomers are using their Schmidt to compile a sky atlas, which can then be used to guide the 200-in. to sectors of the sky calling for more detailed examination.

(*Right*)—This diagram, from Dr. David S. Evans's book, *Frontiers of Astronomy*, brings out the purpose for which the Schmidt camera was devised. The human eye has a wide field of vision: the ordinary telescope magnifies, but restricts the field: the Schmidt camera gives a wide field with high resolution, so photographs taken with it can be greatly magnified.

(*Courtesy, Sigma Books.*)

Professor Zernicke's historic paper appeared in 1934; Bernhard Schmidt produced his first camera in 1930; electron optics began in 1932. These are the key dates of modern optics. (Modern colour science is of equally recent origin, a fact recognised at the conference by the inclusion in the programme of several papers on spectrophotometry.) The three devices that spring from these original contributions are: the phase-contrast microscope, the improved reflecting telescope, the electron microscope.

The contributions made by Schmidt and Zernicke are difficult to describe accurately in non-mathematical terms, but it is possible to convey verbally a sense of their revolutionary significance.

The Schmidt contribution sprang from his knowledge of one of the chief defects of the reflecting telescope, about which a word or so of explanation is necessary. One very important property of a telescope is its *resolving power*, the property by means of which fine detail is distinguished. (It is vital to realise that increased magnifying power without improved resolving power would be useless.)

Another property is the light-gathering power; the importance of this is obvious when one recognises that a telescope has to make visible distant stars whose light is so faint that they are invisible to the naked eye. Both these properties depend on the *diameter* of the objective, whether this is a lens or a mirror. So the biggest practical difficulty that arises in the construction of a bigger and better astronomical telescope is the difficulty of making an accurately figured lens or mirror of great width. It is easier to make an accurate wide mirror than an accurate wide lens. For instance, the famous Mount Palomar telescope has an objective mirror which is 200 inches wide. The biggest objective *lens* in existence, however, is only 42 inches in diameter. Furthermore, reflection from a mirror involves no loss of parts of the spectrum, whereas refraction through a glass lens does (particularly in the ultra-violet). The reflecting telescope, therefore, is a better practical proposition for astronomers who need a very wide objective than is the refracting telescope. All spherical surfaces (whether they belong to lenses or mirrors) introduce distortions, known as aberrations, into the images which are produced by rays other than the few close to the axis. In this respect a paraboloidal mirror has a great advantage over a spherical mirror in that one particular kind of aberration—that known as *spherical aberration*—is avoided. Consequently, when expense is not the major consideration, a large reflecting telescope is usually fitted with a paraboloidal objective. But such an objective is very difficult indeed to make. As Dr. E. H. Linfoot has said, in reference to the meticulous accuracy needed, "Only a very few men living in the world at the present time are capable of producing a 100-inch paraboloidal mirror of this standard of accuracy." This shows how desirable it is to be able to use a *spherical* mirror if it will give results as good as those obtainable with a paraboloidal mirror: for even the latter is not free of aberrations, with the result that the image produced is of good quality at the centre and rapidly deteriorates towards the periphery.

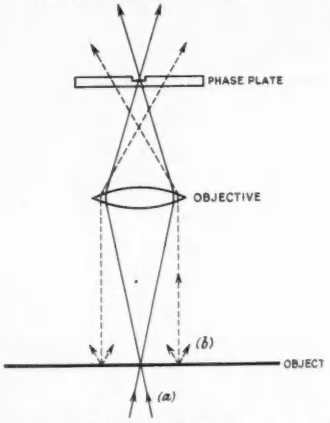
This brings us to the Schmidt camera. Schmidt found a way of correcting some of the aberrations of a spherical mirror. He did this by placing at the centre of curvature of the mirror a special glass which was so shaped that when the incident light passed through it a change of direction was caused that compensated for certain aberrations produced by the mirror. This plate is described as 'aspheric', which means that its profile is designedly not that of the section of a sphere. With this device, first installed at Bergedorf in 1930 and still in use there, sharp photographs are produced over an angular field of 16 degrees.

The Schmidt device was neglected in Europe, but the Americans soon took it up. A Schmidt camera is in use at Mount Palomar, and others exist elsewhere in the U.S.A. Europe has followed. The new 98-inch telescope of the Royal Greenwich Observatory is designed to be used as a Schmidt camera; but in addition, when the corrector plate is taken out and a reflector put in its place, the instrument becomes a reflecting telescope suitable for spectroscopic work. Both St. Andrews and Cambridge universities are acquiring Schmidt cameras.

Dr. E. H. Linfoot and Dr. C. R. Burch are probably the best known of the British scientists to follow up Schmidt's ideas. In 1946 Dr. Burch exhibited an apparatus that he had designed for the making of aspheric surfaces. A year later he showed an aspheric surface used with the mirrors of a reflecting microscope. Reflecting microscopes of this and other types have aroused much interest in recent years, and their development is part of the story of modern optics, a fact acknowledged by the inclusion of three papers on the subject in the volume under discussion.

The optical development started by Professor Zernicke is much more difficult than Schmidt's to describe without mathematics, and indeed one has to be very careful when attempting a non-mathematical description of the principles of 'phase-contrast' microscopy. On the assumption that light travels in waves, the word 'phase' means the position in time or space of the wave. If there are two simple waves passing one spot, then it is possible for the maximum of one wave to coincide with the maximum of the other. The two are then said to be 'in phase'. On the other hand, if the maximum of one wave coincides with the minimum of the other, the two are '180 degrees out of phase'. This degree of phase-difference with two light-waves would result in the cancelling of one by the other (if they were of equal intensity), and this complete interference would produce darkness from the two waves.

Our eyes are not sensitive to changes in phase as such, and the same thing applies to a photographic plate. Only when out-of-phase waves reach the same part of the image and so interfere can the phase-difference produce a change in intensity, and so be visible. This is the trick that Professor Zernicke has worked. The result is that many preparations (especially biological ones) that show hardly any structural details when observed through an ordinary microscope, nevertheless contain parts which differ sufficiently in either thickness or refractive index to produce phase-differences in the emergent light. By retarding or accelerating some of the light, by means of a special device called a 'phase-plate', these phase-differences can be made to cause interference and so produce visible differences in intensity from one part of the image to another. Thus structural details which may not be accessible to differential staining techniques are rendered visible. In metallurgy, too, the phase-differences in the light reflected from parts of a surface can be made to produce phase-contrast images.

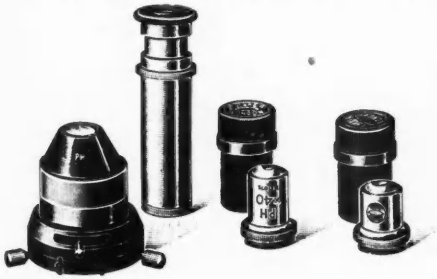


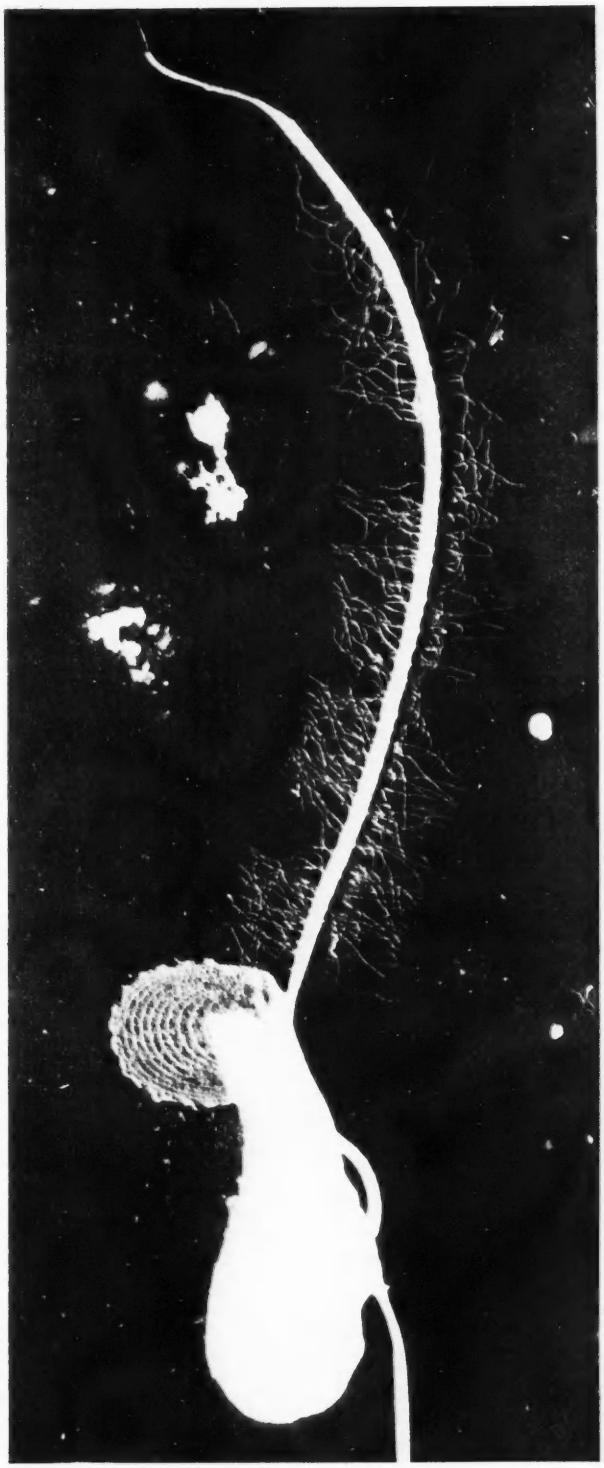
(*Photo at top of column.*) Phase-contrast makes it possible to study living cells without staining them. This still, from a phase-contrast film by Dr. K. Michel, shows cell division in a grasshopper's sperm-mother cells. (*Courtesy, Kodak Ltd.*)

(*Above.*) The principle of phase-contrast microscopy. Different parts in the microscopic specimen have slightly different refractive indices, and this leads to different phase-changes in the light (*a*) focused on the object and passing through it; this light is out of phase with the light refracted (*b*) by the object, and interference patterns result.

(*Below.*) Commercial phase-contrast accessories. (*Courtesy of C. Baker of Holborn Ltd.*)

(*Right.*) Electron Micrograph of male germ-cell (spermatozoid) of *Fucus serratus*; magnification, 16,000 times. The hairs fringing the long flagellum are not visible under an ordinary optical microscope. (*By courtesy of Prof. I. Manton and B. Clarke.*)





Readers will recall the article by Dr. A. Hughes (DISCOVERY, September 1947, p. 270) in which some photomicrographs obtained by this technique were reproduced, and they will be interested to see the remarkable phase-contrast photographs that illustrate Dr. Hughes's book, *The Mitotic Cycle*, which Butterworths Scientific Publications are bringing out next month.

The amount of work that has sprung from Professor Zernicke's analysis is enormous, both practically (in the actual production of phase-contrast microscopes) and theoretically, a fact that justifies Sir Thomas Merton's tribute to the greatest modern worker in the field of optics.

A Revival of the Aether?

IT IS DIFFICULT to recapture the spirit and feeling of past centuries, and almost impossible to enter imaginatively into disputes which happened long ago. For instance, could anyone under fifty work up any excitement today over the issue of Free Trade versus Protection? Yet this was a controversy that was maintained with an incredible acerbity and did not stop short of physical violence.

The world of science, too, has witnessed some bitter controversies; there was, for example, the argument in optics, which went on and on and on, between the corpuscularians and the wave-theory believers. This led to one particularly notorious incident: Lord Brougham's review of Thomas Young's work, a piece of criticism so spiteful that it drove Young out of physics for several years. This same dispute destroyed the long-standing friendship between two famous French scientists who became involved in the running battle which was being fought everywhere between the corpuscularians and those who believed that light was a form of wave motion.

It cannot be said that controversy about the aether and its properties ever reached similar depths of desperation. Nevertheless it was a thorny topic that engaged the attention of leading physicists for much of the nineteenth century. The aether, it was said, was a medium that pervaded all space and all matter in the universe. It was undetectable by any known scientific technique—weightless, odourless, invisible, untouchable, tasteless, and in every way unmeasurable. Yet most scientists believed in it. The renowned Dutch scientist Lorentz believed in it, and he died only just over twenty years ago. So did Sir Oliver Lodge. Yet by 1950 it was impossible to find a scientist of standing who was prepared to discuss it. As W. P. D. Wightman wrote in his recent book, *The Growth of Scientific Ideas*, with reference to the search for an aether, "A few optimists are still searching, but most have given up the task as meaningless." A physicist of high rank, Professor William Wilson, wrote in *A Hundred Years of Physics*, published this year, "The aether is the Mrs. Harris of physical science."

Now in 1951 there are signs of a return to the aethereal faith. Viscount Samuel, our new aethereal minstrel, advocated it at the Edinburgh meeting of the British Association in August. And since then has come Sir Edmund Whittaker's book, *History of the Theories of Aether and Electricity* (Nelson, London, 2nd edition 1951, pp. 434, 32*s*. 6*d*.). In his preface he writes, "It seems absurd to retain the name 'vacuum' for an entity so rich in physical properties, and the historical word 'aether' may fitly be retained." These two facts may mean that a new chapter is to be added to the chequered story of the aether.

It was Descartes who first postulated the aether. He could not tolerate the notion of action at a distance, for he accepted the traditional belief that a force could only be exerted by impact or pressure: the moon affected the tides, so therefore there had to be something between the earth and the moon to convey the force. This something was the aether.

Huygens, who first put forward a coherent wave theory of light, called upon the aether as a subtle medium penetrating all matter in order to explain the propagation of light, which was known to pass through a vacuum and through the millions of miles of rarefied space separating the sun and the earth. A wave implied a medium to carry it. That medium was Huygens's aether, sometimes called in this connexion the *luminiferous* aether. Newton's non-acceptance of the wave theory put the aether out of court for some time, but it returned in strength when Young and Fresnel established the wave theory at the beginning of the nineteenth century. And here another difficulty arose, for if light consisted of *transverse* waves then the aether could no longer be imagined as a sort of rarefied fluid. It had to have some of the properties of a solid in order to resist a change of shape in the transverse direction and so allow the wave to continue on its course without dissipating its energy.

By the time the wave theory was established, and this happened after it had been conclusively shown that light travels more slowly in water than in air, the aether was called upon in order to explain phenomena other than gravitation and light. There were the phenomena of action at a distance in magnetism and electricity—the attraction and repulsion of electrically charged bodies, for example, and the attraction and repulsion of magnets. Theories of the aetherial medium now multiplied rapidly. Laplace put forward a 'gravific fluid' to account for gravitational action at a distance. B. Riemann suggested an aether that could resist compression and also changes of orientation; the former property would account for gravitational and electrostatic effects, and the latter for optical and magnetic effects. The late Lord Kelvin, at the age of seventeen, proposed an analogy between heat and electricity. Of this Clerk Maxwell wrote later, "This paper first introduced into mathematical science that idea of electrical action carried on by means of a continuous medium, which, though it had been announced by Faraday, and used by him as the guiding idea of his researches, had never been appreciated by other men of science, and was supposed by mathematicians to be inconsistent with the law of electrical action, as established by Coulomb, and built on by Poisson." Maxwell himself eventually established equations based on an aether, equations that showed that electromagnetic disturbances would be propagated with the speed of light, a fact never since doubted. And still scientists went on conjuring up new models based on aether—they imagined all sorts of things, such as elastic solids resistant only to rotatory strains, vortices, and so on.

For a full account, at graduate level, of classical theories of the aether, readers must refer to Sir Edmund Whittaker's book. A second volume of this work is to be published, and this will deal with modern developments of the aether

theory. This will tell the story up to the time of the relativity theory and quantum theory. The break between the two volumes is logical, for it was Einstein who turned physicists away from any further efforts at imagining an aether, and he relied only on observable phenomena and discarded imaginary models. The position now is that mathematical equations express observed facts and generalise them. So the aether of Sir Edmund Whittaker is now likely to be a medium satisfied by certain equations, in other words a mathematical abstraction. This is not the case with Viscount Samuel's paper to the Edinburgh meeting of the British Association. He insisted then that his concept of the aether as quiescent energy "is not put forward as a logical assumption invented to account for phenomena otherwise inexplicable, but as presenting a real factor in the universe". The only comment we can make on this is, It all depends on what is meant by *real.*

Professor P. A. M. Dirac of Cambridge, Nobel prize-winner and one of our most original mathematical physicists, has recently joined those who, like Prof. Whittaker and Lord Samuel, now believe in an aether. In a letter to *Nature* a few weeks ago he said that "we are rather forced to have an aether". The arguments leading to this conclusion are entirely mathematical and based on quantum mechanics. The development of this very modern branch of theoretical physics has in fact had as important an effect on the aether situation as Einstein's relativity in 1905, but in the opposite direction. The gist of Professor Dirac's argument is that in his new theory of electrodynamics there is a velocity that plays a fundamental part though it occurs in equations that cannot all be verified experimentally. Such equations as these represent theoretical idealisations. Of this velocity Professor Dirac writes: "It is natural to regard it as the velocity of some real physical thing." It is this thing, never so far demonstrated experimentally, that constitutes the Dirac aether.

British Atom Bomb Production

BEFORE Parliament adjourned for the Christmas recess, Mr. Churchill made a very brief statement during the defence debate of December 6 on the British production of atomic bombs. Its brevity and extremely guarded character suggest that the new Government had not yet had the time to review all the relevant facts and was therefore in no position to make any more detailed announcement. The gist of the statement is as follows, and we quote Mr. Churchill's exact words:

There are only one or two points to which I must refer. Statements have appeared in the Press suggesting that we contemplate widespread departures in the policy of manufacturing atomic bombs. Two years ago I commented unfavourably on the fact that the Socialist Government had not been able to make a specimen atomic bomb although they had been trying to do so for four years. When we came into office, we found that a great deal of work had been done, not only on making the crucial materials required for making atomic bombs, but in preparing to manufacture these weapons. Considerable if slow progress has been made.

The House will realise that this is not the moment to discuss the British research and manufacture of atomic bombs in detail. All that I will say is that we have taken over the very costly production of the Socialist Government. We hope in this as in other matters, by different methods of organisation and administration, to effect some improvements, and there are certain aspects of this delicate subject which I hope we may clarify by discussions with the United States authorities.

The biggest difficulties which the Government has to face are nearly all associated with the fact that the demands made upon the British industrial effort are excessive unless there is a substantial increase in our productivity all along the line. A number of factors, of which shortage of certain skills and kinds of labour, and shortage of raw materials, are two of the most obvious, severely restrict the total industrial effort of which this country is capable, and our maximum effort can only achieve the maximum benefits if there is a carefully balanced system of priorities to ensure that no individual part of that effort is wasted. In the atomic energy field organisational changes are undoubtedly needed. The atomic energy project was treated in 1946 as just another job to be put under the Ministry of Supply. This arrangement has not proved thoroughly satisfactory, and it is now clear that the pace of atomic *development* has been slower than the pace of scientific progress in the atomic field. During the recess Mr. Churchill, together with Lord Cherwell, will be discussing atomic energy development, among many other matters, in Washington and Ottawa. They will have the opportunity of finding out what are the special features of the U.S. atomic project that have rendered it so successful in solving its development problems. Here American information and experience can be invaluable when it comes to deciding on the organisational changes necessary before the British atomic project can get out of low gear is certain. It is to be hoped that Mr. Churchill or Lord Cherwell will be able to make a further announcement on atomic matters soon after Parliament reassembles on January 29.

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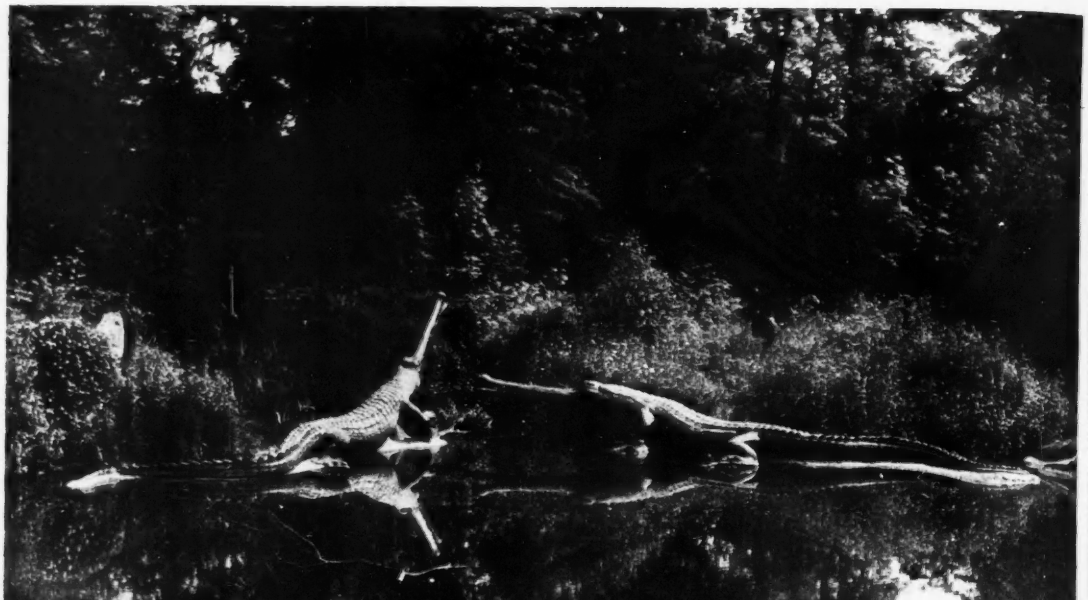


FIG. 1.—A prehistoric crocodile scene at Sydenham, with the full-scale models of Teleosaurus, of which abundant fossils occur in Jurassic rocks.

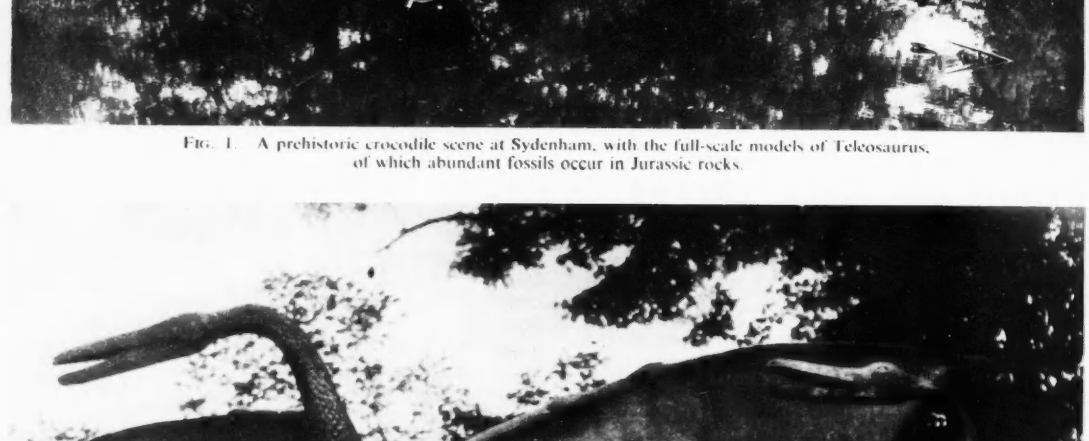
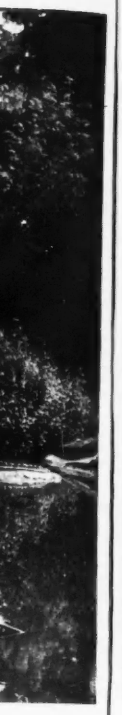
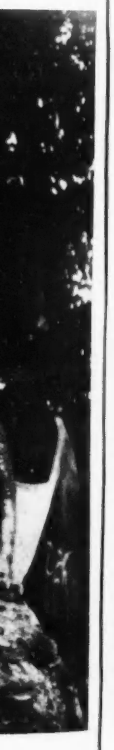


FIG. 2.—The group of Pterodactyls mounted on imitation strata.





The Prehistoric Animals of the Crystal Palace

W. E. SWINTON, Ph.D., F.R.S.E.

Now that the Festival of Britain is over, there is talk that some of its buildings may go to the Crystal Palace, where they would join the remnants of the 1851 Exhibition. Indeed, one of the good things about the Festival has been the interest it has created in its great predecessor. Including its benefits to education, both public and private, the most obvious benefits which derived from that legacy were the colleges and museums of South Kensington and the series of 1851 Research Exhibitions which set men of science like Rutherford on their careers.*

There exists another interesting link with the scientific side of the 1851 Exhibition. When the Exhibition was all over, in 1854, the great glass building which had housed it was moved to Sydenham where, as the old and familiar Crystal Palace, it remained and was used for a variety of functions until it was destroyed by fire in 1935. Today much of that site is desolate. Yet in the pleasant grounds that were laid out around the Crystal Palace there linger still some of the contemporary aids to public instruction. There is, for instance, the island with many of the original models of prehistoric animals, while on the nearby slopes one can still see the displays of geological structures that were once the scene of lectures for parties of visiting students. If they are not so frequently visited nowadays, at least they are not neglected. Each of the animals on the island or on the little beaches has been painted in the appropriate green or blue or red. Each is clearly identified on a bright red signboard with golden yellow letters.

Certainly no one can say that the reconstructions were made as a result of hurried investigation or of shoddy work. Most of them were modelled under the direct supervision of Professor Richard Owen: one of the greatest comparative anatomists of all time. The actual models were made by Waterhouse Hawkins, a well-known sculptor who specialised in such models.

The range of creatures covered by this collection of models includes most of those which had aroused interest in England about the time of the Exhibition. Most of the models are of the large reptiles known as Dinosaurs, but reptiles of the air, the Pterodactyls, and representatives of the sea-going saurians, the Plesiosaurs and Ichthyosaurs and the giant Mosasaurs are also figured.

A most interesting group of models is devoted to the Iguanodon. The first evidence of this large dinosaur had been found in Sussex in 1822, and an important discovery at Maidstone in 1834 had filled in many details of a picture which intrigued anatomists and palaeontologists in the early 1850's. Today the stucco models on the island bear testimony to the interpretations of a century ago. Iguanodon now stands as a great green creature with a bright yellow 'waistcoat'. Its body is covered with overlapping green scales, much like the tiles on the roof of a garden-village house. Along the centre of its back is a row of scales. The head is large and bears a horn on the snout; the animal is without teeth or beak in the front of its mouth. The Iguanodon is shown crouching on all four feet, each of which bears five toes.

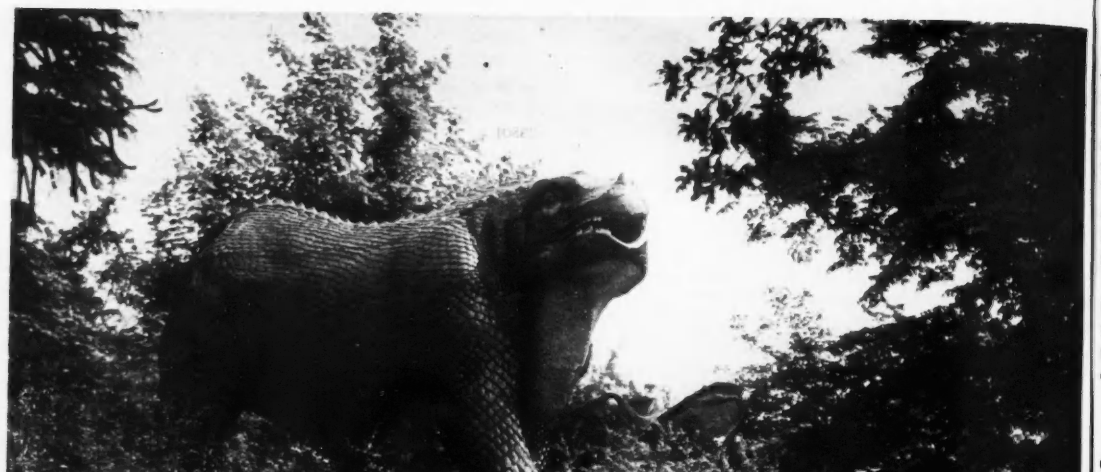
Behind this model one sees two swan-like pterodactyls, and next to it is another model iguanodon which is fondling a small tree trunk and gazing with an ancient but watchful eye. Near by is another dinosaur, this time an armoured one called Hylaeosaurus, which was one of Dr. Gideon Martell's discoveries of 1832. The model stands encased in imitation plates of bone, and its head is turned away as if in shame.

There is, in fact, little to be ashamed about, even though a modern model of Iguanodon would not be constructed on the lines which Waterhouse Hawkins adopted. We now know that the head carried a beak in front of the jaws, and that there was no horn on the snout. We know also that the animal usually walked on its hind legs, its smaller forelimbs being used only when resting and when eating. The horn that used to be placed upon its nose now fits more naturally into position as a thumb! The hand had, it is true, five toes, but the feet had only three, as is shown by the many footprints which have been found in the south of England. The true ornamentation of the skin is now known, but this and the other details were gathered long after these models were made. In any event let us not forget that in a book about the statues which was published in 1854 Professor Owen cast doubt upon both the scales and the horn. The Hylaeosaurus model, however, was based on quite inadequate information. Waterhouse Hawkins made a similar set of models for Central Park, New York, but they aroused the ire of the mayor, who considered them monstrosities contradicting the testimonials of revealed religion, and had them broken up and cast into the lake.

Though the English models have survived in a state of excellent preservation, the success of their struggle for existence has not always seemed so assured. Professor Owen's grandson, writing in 1896, had some hard things to say about them. Deploring their dilapidated condition, he relates this result of neglect to the public's uncertainty about the purpose of the models and says: "How far the labours of Professor Owen and other learned men in setting forth these extinct creatures in the Crystal Palace grounds have succeeded in educating the minds of the British public may perhaps be considered as doubtful." He continued: "The writer lately made a pilgrimage to the Crystal Palace and succeeded in making a surreptitious landing upon the island where the forms of the extinct monsters are displayed. Here he found the specimens in question slightly dilapidated as to the tails and other extremities, together with a total absence of anything like explanation, or even the names of the creatures."

Today, in 1952, these models are 99 years old, but they have worn well and must appear as fresh as ever they have done, thanks to the care their custodians have taken.

* A large part of the proceeds of the 1851 Exhibition was set aside for the encouragement of scientific research. The award by the 1851 Commissioners of Research Exhibitions, each of which was originally worth £150 a year, to candidates nominated by British and Dominion Universities and desirous of continuing their studies at another university, represents one of the best investments ever made with money from that fund.



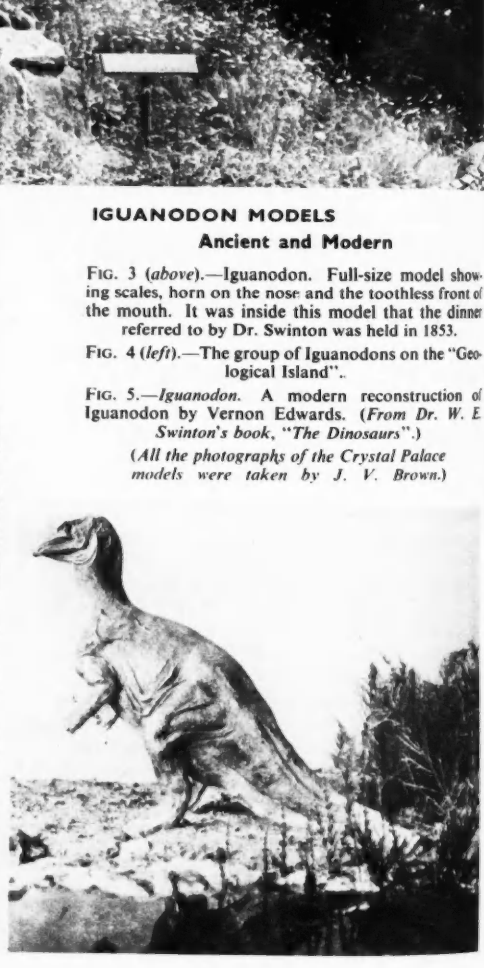
IGUANODON MODELS
Ancient and Modern

FIG. 3 (*above*).—Iguanodon. Full-size model showing scales, horn on the nose and the toothless front of the mouth. It was inside this model that the dinner referred to by Dr. Swinton was held in 1853.

FIG. 4 (*left*).—The group of Iguanodons on the "Geological Island".

FIG. 5.—*Iguanodon.* A modern reconstruction of Iguanodon by Vernon Edwards. (*From Dr. W. E. Swinton's book, "The Dinosaurs".*)

(All the photographs of the Crystal Palace models were taken by J. V. Brown.)



The most striking of the exhibits represent dinosaurs, and we should remember that at the time when they were created the word 'dinosaur' was but twelve years old. Today it is a household word, while splendid discoveries which have been made in every continent, in particular Belgium and the United States, have transformed the picture of their living appearance and our ideas about their habits. Though the advance of knowledge has made some features of the models out of date, we should not decry the work of those who planned this small but enduring exhibit, for new knowledge has accumulated rapidly in the past century.

On a recent visit to Sydenham the writer saw some small boys cross to the island and actually enter the large Iguanodon through an opening on its under surface. Whatever may be the views of the authorities about this practice, the children have ample and distinguished precedent for it. When the models were completed in 1853 Mr. Waterhouse Hawkins, their creator, gave a dinner-party to all those who had been concerned in the work. The dinner was held inside the body of the Iguanodon, on a Saturday afternoon in March, 1853. Actually twenty-one persons, with Professor Owen as their guest of honour, sat down at tables inside the model, while seven lesser dignitaries were accomodated on a platform arranged at the same level outside the animal. Iguanodon when alive was a vegetarian so we can be sure that no living specimen ever contained so much good meat as that effigy did on that Saturday afternoon!

During these ninety-nine years the models have been in the custody of the Trustees of the Crystal Palace, to whom credit is due for their present good condition. Now, on the 1st of January 1952, they have entered the service of the London County Council.

REMAKING NATURE IN RUSSIAN WATERS

Over vast areas of Russia, thousands of people are working enthusiastically to fulfil the great plans for 'remaking nature', which involved such projects as the building of gigantic irrigation canals and reservoirs which are part of the programme which aims at increasing the fertility of arid regions. These schemes will in time have a considerable effect on the seas of Russia; the flow of fresh water into the Aral, Azov, Caspian and Black Seas, for example, will be reduced, and by 1970 it is expected that the salt content of these seas will be appreciably higher than it is now. At first glance such a change would seem unimportant, yet in fact a comparatively small change in salinity can have a sharp effect on both the composition of the fauna and the number of animals living in these seas.

Soviet scientists have been studying this problem, and already some successful experiments have been carried out in the Caspian on the acclimatisation of marine animals.

On the initiative of Professor B. S. Ilyin, in the early thirties the mullet was transplanted from the Black Sea to the Caspian Sea. In past geological eras, when these two seas were connected, the water contained considerably less salt than is the case today, and no marine organisms were present. Then the mullet of the Mediterranean migrated into the Black Sea through the Bosphorus. By that time the Caspian had become closed. The mullet we introduced there have multiplied, and for many years fishermen have been making good catches of mullet in the Caspian.

Formerly the Caspian lacked marine worms or shrimps, which serve as food for many fish. And yet the sea is heavily stocked with fish, which need an enormous amount of nutriment. The sea-worm *Nereis* was introduced into the Caspian Sea, and has multiplied exceedingly. At the suggestion of Prof. L. V. Zenkevich and his fellow-workers at the All-Union Institute of Sea-Fish Industry and Oceanography, 65,000 ragworms (*Nereis*) were brought to the Caspian Sea from the Sea of Azov, where this worm is a favourite food of sturgeon and other fish. The sea-worm feeds mostly on organic matter present in the silt that covers the sea bed. The ragworms have acclimatised well and have spread over an area of 11,500 square miles; they have become the main food of the sturgeon and other fishes.

The successes in the Caspian Sea open up possibilities of changing the fauna of other seas. There is, for example, the possibility that salmon, flounders, the Kamchatka crab, oysters and many other edible animals could be acclimatised in the Barents, White, Black and Baltic Seas. The rivers of the Far East, particularly the Amur, can provide many valuable kinds of animals worth transplanting.

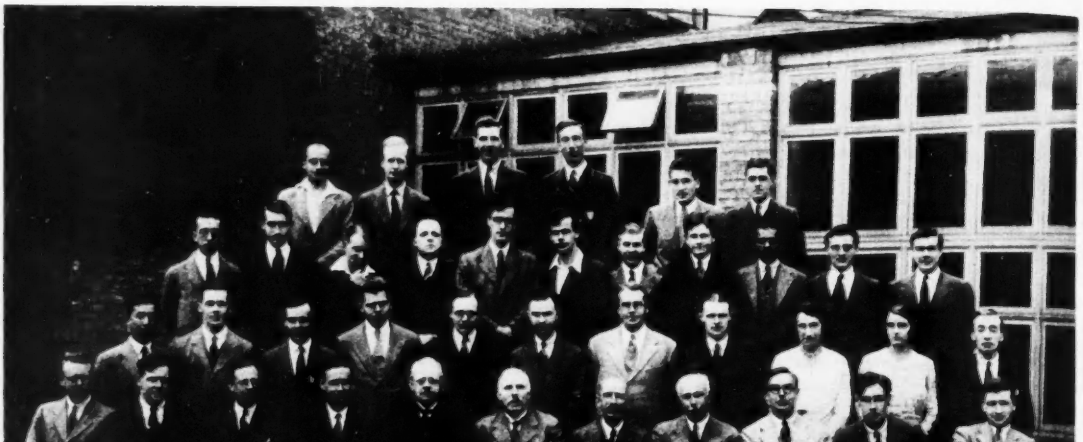
The building of hydro-electric installations on the Volga will also produce changes in the Caspian Sea, and it is interesting to speculate how it will affect the fish population. Caspian fishes fall into three groups. Firstly, there are those species which spend their entire life in this landlocked sea, many of them moving northwards to spawn in colder water. Secondly, there are the species which favour the less salt parts of the sea, and which spawn in the lower reaches of the rivers which feed into the Caspian. Thirdly, and finally, there are the migrant fish like salmon which travel thousands of miles up the rivers to spawn; some of these, for instance the white salmon, penetrate as far as the little tributaries of the Ufa and White rivers.

Naturally, the building of hydro-electric dams will affect these fishes. Regulation of the water flow will create difficulties for the migrant species, and it will also affect those fishes whose young live in the river sand in the shallow parts of the Caspian. But bypasses can be provided to carry migrant fish around the dams. Suitable spawning grounds can also be created.

Big stocks of valuable species of fish are being built up, so that they can be introduced into congenial waters when the occasion arises. Every year over three million eggs, over two billion larvae, more than one hundred million fry and three hundred thousand young fish are put into rivers, lakes and ponds. The fish farms breed stocks both of freshwater fishes and sea fishes that spawn in rivers.

On special fish farms the following kinds of fish are being bred so that they can be used to stock new waters and depleted waters: Salmon (including the white salmon; the hump-backed salmon; and the Baltic, Caspian and Black Sea forms of *Salmo salar*), the two kinds of trout known as *Salmo trutta* and *Salmo fario*; *Coregonus autumnalis* (a fish of herring-like shape which resembles the gwynia and pollan of Britain and the houting and marine of Europe), grayling, sturgeon, carp (*Cyprinus carpio*), tench, and *Alburnus chalcoides* (a species related to the British blean).

Professor V. G. Bogorov.



1932 was the most exciting year in the history of the Cavendish Laboratory, and this photograph of the staff and research students is historic for it was taken in June of that year. Eight Nobel prizewinners are included in the group, the key to which appears below: these are—J. J. Thompson (Physics, 1906), Rutherford (Chemistry, 1908), Aston (Chemistry, 1922), C. T. R. Wilson (Physics, 1927), Chadwick (Physics, 1935), Blackett (Physics, 1948), Cockcroft and Walton (Physics, 1951).

KEY.—*Back Row:* N. S. Alexander, P. Wright, A. G. Hill, J. L. Pawsey, G. Occhialini, H. Miller.
Second Row: W. E. Duncanson, E. C. Childs, T. G. P. Tarrant, J. McDougall, R. C. Evans, E. S. Shire, E. L. C. White, F. H. Nicoll, R. M. Chaudhri, B. V. Bowden, W. B. Lewis.
Third Row: P. C. Ho, C. B. Mohr, H. W. S. Massey, M. L. Oliphant, E. T. S. Walton, C. E. Wynn-Williams, J. K. Roberts, N. Feather, Miss Davies, Miss Sparshott, J. P. Gott.
Front Row: J. A. Ratcliffe, P. Kapitza, J. Chadwick, R. Ladenberg, Prof. Sir J. J. Thomson, Prof. Lord Rutherford, Prof. C. T. R. Wilson, F. W. Aston, C. D. Ellis, P. M. S. Blackett, J. D. Cockcroft.

The Cavendish's Golden Year

A. W. HASLETT, M.A.

IF there was a golden age in nuclear physics, it was from 1931 to 1934, and perhaps for some few years later. During that period discovery crowded fast on discovery, Rutherford stood at the height of his stature, the words 'security' and 'classified' suggested only their standard dictionary meanings, and the physicists' apparatus did not cost the fantastic sums of money which today the Treasury grants without turning a hair.

If there was a golden year, it was 1932, as we have once again been reminded by the award of a Nobel Prize to Sir John Cockcroft and Professor E. T. S. Walton. In a period of just over six months, there were published three letters in *Nature* and one in *Science* each of which gave a preliminary report on work which was later recognised by the award of a Nobel Prize. Begin the count three months earlier and another Nobel prizewinning discovery is included (the discovery of heavy water) and one prizewinning invention—Lawrence's cyclotron.

Extend the record further, to 1933, and the Joliot-Curies have produced artificial radioactivity. Little wonder that some of the Nobel awards for work belonging to that period have been long in coming; little wonder that the reading of the journals containing the first news of the new developments created a sense of expectancy which is now difficult to recapture. In those days physicists and laymen crowded alike to hear Rutherford lecture at the Royal Institution, and Rutherford himself used to telephone his laboratory late at night to hear the progress of the Cavendish's latest experiment.

Such was the pace of progress that it was necessary for Rutherford, when opening a discussion at the Royal Society in the early summer of 1932, to add a stop-press to the printed summary of his statement which had been circulated. That stop-press contained the news of the Cockcroft-Walton experiment in which the first transmutations by laboratory-accelerated particles were effected.

Professor E. O. Lawrence's cyclotron was by then already working at Berkeley, California. To quote Rutherford's description, this was "an ingenious method ... whereby, by using multiple accelerations, protons have been obtained of an energy corresponding to about one million volts". This idea had been put forward in 1930, it was first tested up to the equivalent of 80,000 volts, and its operation at one million volts was reported to the annual meeting of the American Physical Society which was held at New Orleans in December, 1931. Only a small margin of time separated the achievements of Lawrence and the Cambridge workers. The difference between them was in approach. Cockcroft and Walton worked to a definite target, and they used methods and components known already to be practical. With an earlier apparatus, of which a description was published in 1930, they reached 300,000 volts. As was shown by their own later work, they must have produced disintegrations at this time. However, they could not be sure that they were achieving this desired result, and they concluded that protons of higher energy were needed. They took 800,000 volts as their next target, and reached it by a method of voltage multiplication: they multiplied 100,000 volts to 800,000 volts by means of a combination of condensers and valves used as switches. Lawrence, on the other hand, was developing his own novel method, and for him the sky was the limit: he reached 500,000 volts as an intermediate stage, but pushed on to one million; no sooner had he reached one million volts than he was thinking of ten million. With the addition of some further new ideas, his original cyclotron remains as the parent of all existing machines for the acceleration of protons and heavier particles to very high energies.

For the observer in England, the record of 1932 began with the arrival of the *Physical Review* for January 1. This brought the news that Professor H. C. Urey and G. M. Murphy of Columbia University, in collaboration with F. G. Brickwedde of the Bureau of Standards, had obtained fairly convincing evidence of the existence of heavy hydrogen atoms of mass 2, and that they had made some progress towards its concentration, by evaporation of liquid hydrogen at a low temperature. This also was mentioned by Rutherford in his review, though the work was at an early stage. Heavy water was yet to be concentrated effectively by long-continued electrolysis; yet to come were the use of its nuclei, deuterons, as bombarding particles in nuclear research; its application to the tracer method; and the unavailing arguments of Rutherford in favour of 'diplogen' and 'diplon' to avoid verbal confusion with neutrons (one of his few failures). The discovery had also its domestic interest for the Cavendish, since the search for heavy hydrogen had been prompted by the accuracy of Aston's determinations of atomic mass at an earlier period.

The sequence of Cavendish contributions began on February 26, with a letter from Dr. (now Sir James) Chadwick, published in *Nature*, on the possible existence of the neutron. Oddly enough—seeing that Chadwick himself was essentially of a retiring disposition—this discovery did not lack for publicity. The explanation of why it was well publicised is that a friend of Chadwick's who was working in the Cavendish took the necessary steps (unknown to Chadwick!) to ensure that the letter should be read by suitable individuals in Fleet Street, and that its full significance should be appreciated. It also happened that Rutherford was scheduled to give a Royal Institution lecture not quite three weeks later; and, in the second half of his lecture, he gave the first full account of the events leading to the discovery of the neutron and of the Cavendish experiments up to that time. The immediate stimulus preceding this discovery was an experiment by the Joliot-Curies in Paris, which they interpreted in terms of gamma-radiation of unusually high energy. They would probably have preferred the neutron explanation had they been familiar with Rutherford's Bakerian Lecture of 1920 in which he suggested the existence of a neutral nuclear particle. Under Chadwick's direction, sufficient further experiments were done in the Cavendish to show that the explanation in terms of high-energy gamma radiation was virtually untenable, whereas an explanation in terms of neutrons was free from difficulties.

Cockcroft's and Walton's experiment was summarised in a further letter to *Nature* on April 30. Owing to a series of odd accidents this letter was at first overlooked by the newspapers, and then when it was spotted it was gloriously misinterpreted: at one stage in this comedy of errors, the Press claimed that it was the protons which Cockcroft and Walton had 'split', instead of the lithium atoms which had been bombarded with protons.

By the time of the Royal Society discussion in May, the main outlines of what had been done were beginning to emerge; and it was realised that, although the energy-release from individual atoms was encouragingly big, the proportion of lithium nuclei 'hit' was discouragingly small. The transmutation was not only the first to be effected with particles whose speed could be varied and controlled by the experimenters; we can now see that it also provided the first (though not the best) evidence of the correctness of Einstein's equation, $E=mc^2$, for the relationship between mass and energy. It was thus the basis of all later discussion of atomic energy. This experiment had a lasting influence in nuclear physics; it led, for instance, to the routine use of the mass-energy relationship in laboratory work. The exchange-rate between mass and energy is such as to make energy the easier quantity to measure, so that small differences in mass are best determined by measurements of the energy changes in transmutations. A final summary may be quoted from Rutherford: "It is clear that the successful application of these new methods opens up a new and wide field of research where the effect of bombarding matter by swift ions of different kinds can be examined. Dr. Cockcroft and Dr. Walton are to be congratulated on their success in these new experiments which have taken several years of hard work in preparation." It was a fantastic coincidence that the neutron and artificial transmutation should have been first discussed at the same meeting, but so it was.

The second half of 1932 began quietly, and there was in fact a pause until September in the sequence of publication of discoveries belonging to the category which win Nobel Prizes for the scientists who make them. Two such discoveries came in quick succession, although neither of them attracted so much general attention at the time. First, there came, in a letter to *Nature*, a preliminary account by P. M. S. Blackett and G. P. S. Occhialini of a device by which cosmic rays were made to take their own

photographs—hitherto the usual procedure was to 'expand' a cloud-chamber at random, and to hope that the picture one obtained happened to include a track. This was published on September 3. A week later, in *Science*, C. D. Anderson of the California Institute of Technology published a note on three cloud-chamber tracks which he interpreted as showing the existence of positively charged particles, comparable in mass with that of the electron. This was later confirmed with many more pictures, obtained with Blackett's apparatus. This discovery was important in several ways. Apart from cosmic radiation, it gave additional significance to a difficult theory of energy-states which had been advanced by Dr. P. A. M. Dirac in 1930: this theory fitted the facts that were known about negative and positive electrons, whereas its application to electrons and protons at first appeared to be forced and difficult. Secondly, the positron (or positive electron) was needed within a year of its discovery for the explanation of the new kind of artificial radioactivity discovered by the Joliot-Curies. That discovery belongs to the last quarter of 1933 (it was published in January 1934), and the interval separating it from the previous link in the chain of discovery seemed a long one, for one was accustomed to a rapid tempo. It made a fitting finale to this great period, and of all these discoveries it was the one which appealed most directly to the imagination. There was also an element of poetic justice about it; for it followed the affair of the neutron, which the Joliot-Curies had been so near to discovering but which had just escaped them.

There was a robustness about that period now perhaps somehow lacking. Rutherford boomed on platforms as well as in the Cavendish, and indeterminacy, though it had already arrived, was covered by the confident simplicity of the Rutherford approach. This was an invigorating period, and the Cavendish researches had an immense attraction even for non-scientists. There was for instance the arts don of a Cambridge college who after hearing about the behaviour of the positive electron coined the phrase "the googlie electron, because it breaks the wrong way"—though the word 'swerve' might have been more accurate than 'break'!

One can hardly imagine that he would have been so daring in a world of meson particles, or so cheerful in one of security and atom bombs.

THE PHYSICS NOBEL PRIZE FOR 1951

WHEN Rutherford won his Nobel Prize in 1908 he was surprised to find it was a prize for *chemistry* that he had been awarded. The idea of being a chemist always amused him, and he used to joke about it. A. S. Eve in his official 'life and letters' of Rutherford records his quip to the effect that he had not the slightest objection to being called a chemist provided his chemical friends did not mind! In these days scientists play hop-scotch on the Periodic Table, for the transmutation of one element into another with entirely different chemical properties represents a jump from one square in the table to a different square in a different column altogether, and we can now appreciate the foresight of the selectors of the 1908 Nobel prizewinners who recognised that a new branch of chemistry—nuclear chemistry—had been brought into existence by Rutherford when he effected the first nuclear transformation. Nevertheless it is broadly true to say that in Britain nuclear phenomena have tended to remain a monopoly of the physicists. This is obvious if one checks the list of British scientists who have gained Nobel Prizes for discoveries made in the nuclear field; practically every name in that list is the name of a physicist. Once again the *Physics* Prize has come to Britain, whereas the nuclear chemist who has won the chemistry prize is an American, a fact which reflects the difference between atomic energy development in the two countries.

The Physics Prize which Cockcroft and Walton have been awarded attaches directly to the first successful atom-smashing apparatus with which they split the lithium atom in April 1932. That event was one of the outstanding milestones along the road of progress, comparable in importance with Rutherford's discovery in 1919 of the transmutation of the nitrogen atom, Chadwick's discovery of the neutron (1932), the discovery of nuclear fission in uranium (1938), and the proof that a chain reaction could be sustained in an atomic pile (1942).

Rutherford's 1919 discovery depended on the bombardment of nitrogen gas with energetic alpha particles emitted by radium. For a considerable time such particles were the most useful tool which could be employed to strip down the nucleus with the object of finding out what fundamental particles were involved in nuclear structures. But towards the end of the 1920's it had become clear that some more powerful projectile was needed if more details about the structure of atomic nuclei were to be obtained by the bombardment technique. In 1927 Rutherford had described his next objective; he said it was his "ambition to have available for study a copious supply of atoms and electrons which have individual energy far transcending that of the α- and β-particles from radioactive bodies". Somewhat later he spoke about the experimental difficulties of reaching this target; he said then that in order to obtain alpha particles as swift as those emitted by radium they would need discharge tubes capable of standing 5 million volts, and at least 3 million volts would be needed to obtain electrons as swift and gamma rays as penetrating as those from radium. He added that the highest potential so far applied to a single discharge tube was only about 1 million volts! This definition of the problem was the highlight of a speech he delivered when he opened the new High-Tension Laboratory of the Metropolitan-Vickers Electrical Company at Trafford Park, Manchester.

Two of Rutherford's 'boys' solved that problem, and one of them was an ex-apprentice of Metro-Vickers. His name was John Douglas Cockcroft. Today we usually think of Cockcroft as a nuclear physicist, but this obscures the fact that the very special experience which he took with him to the Cavendish was that of an electrical engineer. Born in 1897 in Todmorden, the Yorkshire town on the banks of the River Calder which played a prominent part in the Industrial Revolution with its development of textile factories, foundries and machine shops, he attended the local secondary school and then went to Manchester

Sir John Cockcroft toured Scandinavia last month, receiving his Nobel Prize in Stockholm after a visit to Norway, where he is seen attending the official opening of the atomic institute at Kjeller (see DISCOVERY, November 1951, p. 339) with Francois Perrin, director of the French atomic energy project.

College of Technology.* After graduation as an electrical engineer, he became an apprentice with Metro-Vickers at Manchester, where he worked in the high-tension section of the insulation-testing laboratory. In his spare-time he continued his studies under the late Prof. Miles-Walker. In 1922 the opportunity occurred for him to go to Cambridge and become one of Rutherford's research students. He had been granted £100 from the War Thanksgiving Education Research Fund of the Institution of Electrical Engineers (of which he was a member), and it was Prof. Miles-Walker who advised him to use it at Cambridge. So, in 1924, Cockcroft started on post-graduate research in the Cavendish. He was somewhat older than the usual post-graduate student, but because of the war many of the students at Cambridge were much the same age as himself —for instance, there was P. M. S. Blackett, born in exactly the same year as Cockcroft, who had gone to the university after serving in the Navy for five years.

The 1920's were a period of great activity at the Cavendish. In one single year (1927–8) we find that no less than fifty-three research papers were published by the Cavendish team which included men such as Chadwick, P. I. Dee, C. D. Ellis, Norman Feather, Oliphant and J. A. Ratcliffe, as well as Blackett, Cockcroft and Walton. During this period a great many bombardment experiments were carried out and by 1928 it was known that the nuclei of thirteen different elements had split under bombardment.

Nuclear chemistry was now a fast developing subject; as A. S. Eve wrote, "At one time physicists looked askance at the Periodic Table as something as remote from physics as the Hebrew alphabet. It is now a vade-mecum, a Bradshaw, a Baedeker!" He was referring to the year 1928.

The early bombardment technique which had given such spectacular results had the limitation that it was intrinsically a 'hit-and-miss' affair; it was effective if the chances of the projectile hitting the target—an atomic nucleus—were of the order of 20 in a million—that is, the technique gave results if 20 projectiles out of a million hit a nucleus. But there were times when it failed completely; as, for example, when uranium nuclei were bombarded with alpha particles. There seemed to be some sort of barrier preventing the projectiles from penetrating to the nucleus. The experimenters were forced to admit that they were baffled, and in fact no explanation of this type of failure was forthcoming until the experts on wave-mechanics had studied the phenomenon. This change of phase, with experimental work yielding its pride of place to the development of theories capable of shedding light on the problem, prompted Rutherford to his sly comment that "The theoretical physicists have got their tails up and it is time that we experimentalists pulled them down again". (Only a few years before, Rutherford had been able to say that the mathematical experts "play games with their symbols, but we, in the Cavendish, turn out the real solid facts of Nature".)

The experimentalists had indeed struck a difficult patch, but it did not disturb Rutherford, for he was accustomed to the idea that the progress of science is like "the progress of man going through a swamp, with islands of firm earth in between". When they would strike firm earth again nobody knew, but Rutherford held to his conviction that there was no kind of atom which would not yield eventually to bombardment; what they needed to do was to put down a different kind of barrage. It was the apparatus designed by Cockcroft and Walton which provided the right sort of

*The outbreak of war in 1914 almost exactly coincided with his move to Manchester; his university career suffered interruption as a result and he saw war service—first with the Y.M.C.A. and then, on reaching military age, with the Royal Field Artillery in France.

barrage, and so enabled the Cavendish team to make a major advance. Cockcroft has said that the starting point of the development which he and Walton contributed was "the belief, which was inspired by new developments in theoretical physics", that the central nuclei of atoms could be penetrated fairly easily by using atomic projectiles (protons) speeded up by the application of only a few hundred thousand volts. The apparatus took between three and four years to build. Here is Cockcroft's own simple description of the apparatus: "We built ourselves a tower of four glass cylinders about 4 metres high which took electricity from a high voltage transformer and turned it into even higher voltage electricity of a steady kind suitable for our experiments. We also stuck together two other glass cylinders, made a high vacuum inside them and applied the high voltage from our tower to speed up hydrogen atoms which we shot into the apparatus." This apparatus is now in the Science Museum.

Bombardment on an altogether new scale was now possible, for from the bottom of the apparatus emerged a stream of protons—at the rate of a million million a second and travelling at speeds so enormous "that they would have crossed the Atlantic in less than a second", to quote Cockroft's own graphic phrase. It was expected that the nuclei of lithium atoms would be most easily split, and so the first target on to which the high-speed protons were directed was a lithium target. The result is now part of scientific history; the protons penetrated to the nuclei of the lithium atoms, each of which proceeded to split into two helium nuclei. Moreover the energy in each pair of flying fragments far exceeded—by about 100 times—the energy in the proton projectiles. That large amount of extra energy came from the conversion of matter into energy.

This experiment opened a new era—of atom-smashing with machines. With the development of the cyclotron even swifter particles became available for use as projectiles, and the 1930's witnessed the construction of bigger and better machines for accelerating particles to speeds which made it possible to spiit atoms with ever-increasing efficiency. Progress in nuclear physics now became very rapid, while this revolution which engineer-scientists like Cockcroft and Lawrence had started radically altered the whole physical appearance of laboratories like the Cavendish. Rutherford gave this description when he was comparing the simplicity of the apparatus he used in 1919 with the elaborate equipment characteristic of 1937:

"At Cambridge a great hall contains massive and elaborate machinery, rising tier on tier, to give steady potential of about 2 million volts. Near by is the tall accelerating column with a power station on top, protected by great corona shields—reminding me of a photograph in the film of Wells's *The Shape of Things to Come*."

Cockcroft had been elected a Fellow of St. John's College Cambridge in 1928, and in 1939 he was appointed Jacksonian Professor in Natural Philosophy in the university. But that year brought a diversion of nuclear science into other channels, which led eventually to the atomic bomb. For in 1939 it was realised that uranium fission opened up the possibility of such a bomb. (As early as March 1939 Fermi brought the idea to the notice of the U.S. Navy Department.) Normal publication of research results in this field stopped, and progress in nuclear physics became top secrets. It is interesting to find that at the beginning of the war Cockcroft wrote to R. H. Fowler, British scientific liaison officer in Washington, advising the investigation of plutonium; quantity production of this fissile material seemed out of the question for Britain, whose resources could better be concentrated on U 235 production, and this idea of Cockcroft's was passed on to E. O. Lawrence.

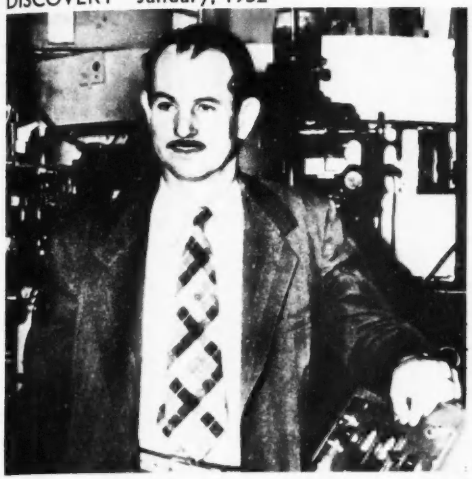
For the greater part of the war Cockcroft served as chief superintendent of the Air Defence Research and Development Establishment. But in 1944 he crossed the Atlantic to take charge of the Atomic Energy Division which had been set up by the National Research Council of Canada. By the end of the war this division had expanded to the stage when it employed 350 people, including 140 research scientists. This atomic project has to its credit the compact but powerful heavy-water pile at Chalk River.

In 1946 Sir John Cockcroft returned to this country to become the first director of the new Atomic Energy Research Establishment at Harwell. The direction of the Chalk River project, where quite a number of Harwell scientists gained valuable experience during the war and after, he handed over to Dr. W. B. Lewis.

The past five years have proved Sir John's qualities as a leader of a research team, and the creation of the Harwell laboratories is a considerable achievement for which he is entitled to much credit. It is true that disappointment has from time to time been expressed at the slowness of British atomic energy developments compared with the American, and Harwell, which must supply much of the driving force for the British atomic project, has not escaped criticism. But Harwell is now a well-established research centre, and given a few more years it can be expected to produce substantial results. When it was announced last year that Cockcroft would be leaving in March 1952 to succeed Sir Henry Tizard as chief scientific adviser to the Government, one could not help feeling that he would miss the satisfaction which would come from seeing Harwell working as efficiently and fruitfully as he planned it to work. Now it appears there has been a change of plan, and Cockcroft will probably not be leaving next spring after all. With Lord Cherwell as its adviser on atomic development, the Government is likely to remove the brake which has been holding back Britain's atomic energy project, and Sir John may well have the satisfaction of seeing the whole scheme go "full steam ahead".

THE 1951 CHEMISTRY AWARD

NOBEL was a man who fully appreciated the obstacles which scientists and inventors have to overcome when they attempt to blaze new trails. One of his few close personal friends has stated that one motive which led to the founding of the Nobel Prizes was "Nobel's wish to provide such complete economic independence for those who by their previous work had given promise of future achievement that they could ever afterwards devote themselves entirely to research". It seems quite clear that he wanted the prizes to afford material help to men of promise rather than that they should be awards given towards the end of a distinguished career in science or medicine as a tribute to past achievement. Nobel would have fully approved of the award of this year's chemistry prize, which is shared by Prof. Glenn T. Seaborg and Prof. E. M. McMillan. They



Professor Edwin M. McMillan (*left*) and Professor Glenn T. Seaborg.

are both far younger than the average Nobel prizewinner; Prof. Seaborg, for instance, will be forty this year.

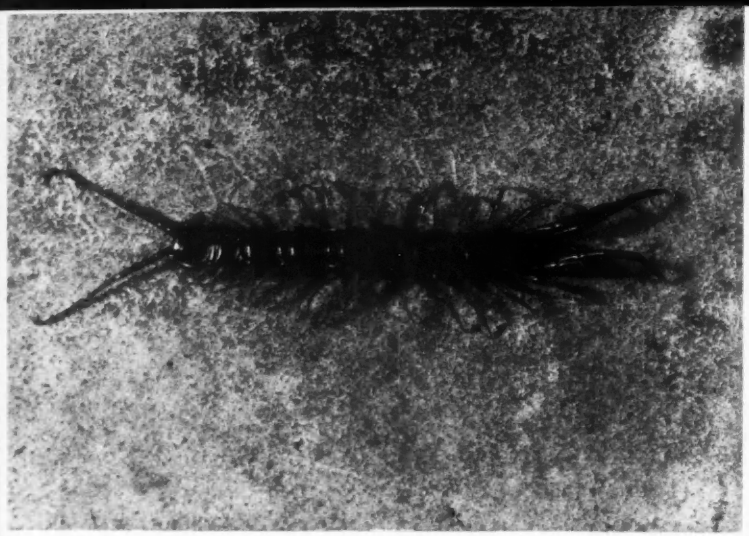
Both of them built international reputations during the war, and with discoveries which had to remain secret for a long time because of their intimate connexion with the atomic bomb project. Their researches were indispensable links in the sequence of development which culminated in the large-scale production of plutonium. Before the war there had been considerable speculation about the so-called trans-uranium elements—that is, elements with atoms heavier than uranium. Today six such elements are known and are included in the Periodic Table; these are elements 93 (neptunium), 94 (plutonium), 95 (americium), 96 (curium), 97 (berkelium) and 98 (californium).

It was Prof. McMillan, in collaboration with P. Abelson, who discovered the first of these—neptunium—early in the war. It is produced when a neutron is absorbed by a nucleus of a U 238 atom, but then itself decays, leaving plutonium. Systematic investigation of these two new synthetic elements dates back to 1940 when, according to the Smyth Report, the nuclear physics team of the University of California began with the bombardment of uranium with neutrons (with a powerful cyclotron); the product was then studied with the object of finding ways of separating the plutonium from the uranium. The investigation of the fission properties of plutonium was also included in their programme. This research produced the results which enabled Prof. E. O. Lawrence, in May 1941, to suggest that a 'super bomb' should be practicable if plutonium could be produced in large enough quantities.

The plutonium project now developed along two main lines; there was firstly the work of Fermi's team which culminated in December 1942 in the achievement of the first sustained chain reaction. This was effected in the world's first atomic pile, and it brought plutonium production from ordinary uranium metal a stage nearer.

Secondly there was the work of the chemists; their task was to develop methods of separating the plutonium produced in the pile from the uranium and fission products associated with it. Seaborg was a key man on this chemical side of the work. The study of the chemical properties of plutonium had to precede any selection that could be made of those properties which could be exploited in a practical factory-scale separation plant. This was a tricky business, because the chemists had to work with very tiny quantities of plutonium—even in 1943 the total amount of plutonium at their disposal was but *one milligram*—so they had to refine considerably the available techniques of microchemical analysis, but they solved these particular problems so successfully that by the end of 1942 "plutonium, entirely unknown 18 months earlier, was considered an element whose chemical behaviour was as well understood as that of several of the elements of the old Periodic Table", to quote the Smyth Report. The chemical team, to which Seaborg belonged and which did this work, was part of the so-called Metallurgical Laboratory of Chicago University.

Once it had been decided that the separation of plutonium from other materials in the pile was chemically possible, the chemists had to work out the details of a practical industrial scheme of separation. This called for a programme of development which brought the industrial chemists and engineers right into the Chicago Metallurgical Laboratory to learn, at first-hand from Seaborg and his associates, the special features of a separation process which would involve handling large quantities of intensely radioactive substances. Between them, the production experts and the fundamental chemists worked out the basic plan of a separation plant. This was built at the Hanford Engineer Works on the Columbia River, and when it was brought into operation it fully justified the confidence which Seaborg and his fellow-chemists had had in their calculations—calculations which had been based on tests made with that almost ridiculously tiny amount of plutonium. The bursting of the second atom bomb over Nagasaki was the final justification of the idea of a 'superbomb' which had been born in the laboratories of the University of California four years earlier. McMillan and Seaborg were outstanding among the scientists who conceived and carried that idea through to its conclusion. In 1939 both were at the beginning of their research careers; at the end of the war, both had won international reputations, and both had received the rank of full professor.



LITHOBIUS × 2

The Biology of Centipedes and Millipedes

CENTIPEDES AND MILLIPEDES are shy, somewhat elusive and generally small creatures, and therefore tend to escape anything more than cursory notice. Yet there are nearly 40 British species in each group—the figure is bigger if subspecies are included.

Centipedes (Chilopoda) and millipedes (Diplopoda) are members of the Arthropoda—as the phylum is called which includes the insects, spiders, crustacea and other animals with jointed limbs and a chitinous external skeleton (exoskeleton). For convenience, the centipedes and millipedes are often grouped together with the microscopic Symphyla and Pauropoda in the unnatural assemblage called the 'Myriapoda'. The structural differences between the centipedes and the millipedes are, however, so marked that they are now recognised as belonging to two separate classes which have evolved parallel with each other. The centipedes have flattened bodies and one pair of legs to each segment of the body, whereas in Diplopoda the body is usually cylindrical or nearly so, and there are two pairs of limbs to each segment. Turning to the appendages, we find that centipedes have long antennae composed of many segments, so that the antennae resemble those of orthopterous insects such as cockroaches; centipedes also possess poison claws, and their reproductive organs have a duct which opens at the posterior end of the body. On the other hand, the antenna in the millipedes is characteristically club-shaped and made up of seven or eight segments; the millipedes' generative glands have ducts which open on the *third* body segment—for this reason they are sometimes known as Progoneata.

Classification

The British species of centipedes are classified in three orders. The first order, the Lithobiomorpha—i.e. 'stone-dwellers'—includes the common brown centipede called *Lithobius forficatus*, and a number of smaller species such as the pale *L. melanops*, and *L. lapidicola*. *Lithobius variegatus* is a large southern species which is easily recognised because of its attractive variegated colour pattern. These centipedes are all found under rocks, fallen leaves, logs and bark; all of the species have 15 pairs of legs, and their antennae have twenty to fifty segments.

The second order, the Scolopendromorpha, embraces three species of *Cryptops* which have a twenty-two-segment body. The most common species is the orange-coloured *C. hortensis*, which is frequently found in flower pots in potting sheds and under bark, etc. It is related to the large tropical centipedes of the genus *Scolopendra* which have gained an evil reputation because of their poisonous bite.

Finally the attenuated centipedes belonging to the order Geophilomorpha ('earth-lovers') usually occur deeper in the soil, and are consequently often discovered while digging. These have 31–173 pairs of legs—they can thus live up to the name of *centipede*—but their antennae have only fourteen segments. Many of them are phosphorescent at night.

The classification of our millipedes is more complicated. There are two sub-classes: the first, the Pselaphognatha, is represented by the tiny bristly millipede called *Polyxenus lagurus* which can sometimes be seen running on the bark of a tree or gliding among the patches of lichen on an old wall.

The second sub-class—the Chilognatha—contains a number of orders, and the majority of millipede species belong here. A well-known example from this sub-class is the British *Glomeris marginata*; this belongs to the Pill-millipede family (Glomeridae) and it is often mistaken for a woodlouse, as it has the same habit of curling up into a ball. (Actually the two can be easily distinguished; the millipede has many more legs than the woodlouse, and the cuticle is much shinier; in the millipede the spiral reflex which causes the animal to roll up into a ball persists for a longer time.)

The largest order within the Diplopoda is the order Opisthospermophora. It contains two sub-orders: the first is the sub-order Spiroboloidea, almost entirely tropical and including some species which reach a foot in length; the second is the sub-order Iuloidea, most members of

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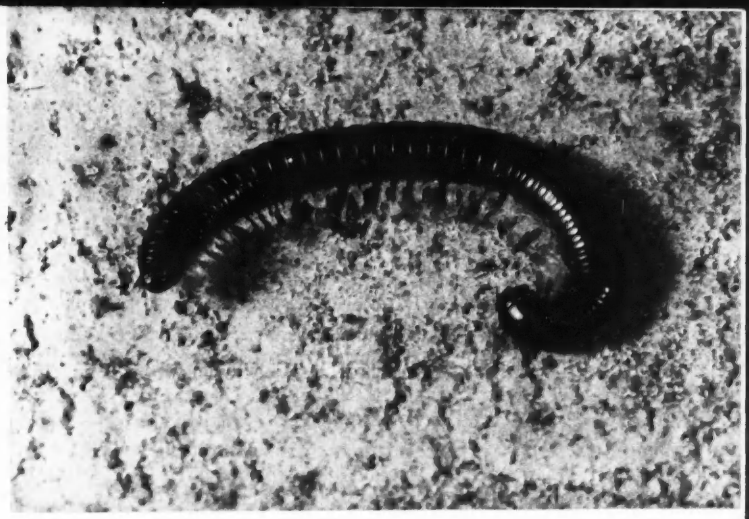


TACHYPODOIULUS × 3

which occur in temperate regions where they are sometimes sufficiently numerous to constitute a farm pest. The chief offenders among British millipedes are the 'false wireworm' (*Tachypodoiulus niger*) which is often confused with the European *Iulus terrestris*, though the latter species is not found in Britain, and the 'spotted snake-millipede' (*Blaniulus guttulatus*), which I shall mention later.

The order Proterospermophora is almost as extensive as the Opisthospermophora. It contains the flat-backed millipedes of the families Polydesmidae and Strongylosomidae which are cosmopolitan in distribution. The temperate forms of these millipede families are small, brownish creatures, but some of the tropical species are large and beautifully coloured. Another order, the Ascospermophora, is represented in Britain by a number of little-known species. The last order, the Colobognatha, has one representative, *Polyzonium germanicum*, which is restricted to Kent, though it may occur in Surrey as well.

Economics

Centipedes are active predators which feed on spiders, insects and their larvae, etc., and they kill their prey by means of the poison claws (maxillipeds). Some of the large tropical centipedes which are a foot or more in length inject poison (said to resemble the poison in the hornet's sting) which can be dangerous even to humans. The temperate species, on the other hand, are quite harmless: indeed, they are usually regarded as beneficial animals because they destroy injurious insects.

There is one aspect of their biology, however, which is less favourable. There are a number of well-authenticated cases of centipedes becoming pseudo-parasitic on man; they have been found living in the ears or nasal sinuses where they cause considerable irritation to the mucous membrane. Centipedes and millipedes have also been found in the alimentary canal, but in most cases of this sort they appear to have been swallowed by people who were mentally unbalanced; to judge from the records, these animals seem to have a weird fascination for the hysterical and insane. It is quite certain, however, that the animals never breed in such unnatural surroundings.

In contrast to centipedes, millipedes are usually vegetarians, although some species have occasionally been found living on decaying carcasses. In spite of their vegetarian diet, however, millipedes do not rank as a major agricultural pest, though the damage to crops done by millipedes all over the British Isles is by no means negligible. The chief offender here is undoubtedly the 'spotted snake-millipede' (*Blaniulus guttulatus*) already mentioned. This small grey species can be recognised by the presence of a row of dark red spots running along each side of the body. It is held responsible for over 90% of the damage due to millipedes reported during the last five years, and every month that passes brings fresh reports of attacks on such crops as sugar beet, potatoes, mangolds, barley, strawberries and peas. The problem of controlling this millipede is not a simple one, however, and tends to be ignored.

Recent research by the author has indicated that outbreaks of the pest tend to occur during a dry spell following a period favouring the reproduction of the species; another necessary condition seems to be that the soil should not be disturbed and should be rich in humus. Experiments have shown that humus and rotting organic matter have a texture which the millipedes prefer to that of living plant tissues. Millipedes are extremely susceptible to desiccation, and it may be that sheer lack of moisture compels them to attack growing plants during periods of drought. Once the attack has started, the sugars in the plant sap could attract them and so account for their not returning to their normal diet of dead organic matter.

It seems unlikely that millipedes can cause primary damage to crops with tough exteriors, such as potatoes and mangolds; their mouthparts are very weak, and moreover millipedes do not seem to be attracted to potatoes, for instance, with unbroken skins. Once an entrance has been achieved, however, through a hole made by wireworms or other pests, a millipede will eat the whole centre out of a potato; lesser damaged one by a millipede is serious when, as frequently happens, it is followed by fungal attack.

Probably the best control measures that can be suggested are to disturb the soil in the spring by ploughing, as this would inhibit breeding; and to inspect the crops during short dry spells, so that outbreaks can be checked at an early stage. (Here Gammexane dust as used against wireworms is effective.)

The cuticle of the millipede resembles that of the insect in possessing three primary layers: the outermost layer (the epicuticle) is composed of cuticulin, which is a lipo-protein tanned by quinones; underneath comes a tanned exocuticle, composed of chitin, and then a soft endo-cuticle which is chitinous and composed of two optically different layers—the first, the outer one, is strongly calcified.

There is, however, no waterproof layer of wax over the cuticle as in insects and ticks, and the rate at which the millipede loses water depends upon temperature and humidity. Water is readily lost and taken up through the cuticle. In spite of the great sensitivity of millipedes to desiccation, the cuticle shows some degree of impermeability; as the exocuticle is impregnated with lipoids, there is some restriction on the rate of water-loss. But the nature of the integument makes for dependence on moist surroundings and so affects the ecology and distribution of these animals.

Enemies

The double hardening of the cuticle (by chemical tanning and deposit of calcium) tends to render millipedes unpalatable to their enemies. Protection from predators is enhanced by bristles, as, for instance, in *Polyxenus*. Moreover the members of the order Chilognatha have a repugnant fluid, which is secreted by glands opening in a row along each side of the body. Experiments carried out by the writer convince him that both millipedes and centipedes are distasteful to most predatory enemies, with the possible exception of amphibia and birds. This secretion in the large tropical millipedes has a strong caustic action on the human skin and can cause it to peel off and leave a wound which heals very slowly. It is dangerous to the eyes, and frequently causes blindness among chickens in the West Indies, for instance. The chemical nature of this fluid is not known, but it may well vary from species to species. In many cases the fluid has a pungent almond-like smell suggestive of prussic acid; the volatile element in the secretion is fatal to small animals.

Although a similar fluid is not secreted by the centipedes (in any case, these creatures are protected by their poison claws), several earth-loving species of centipedes are capable of producing phosphorescent liquids which may have some protective value. The phosphorescence may be excited at any time of year by mechanical stimulation, and by immersion in water; it also occurs when the centipede is attacked by ants and similar enemies. In the autumn, at the time of sexual maturity, these centipedes leave their burrows, and for this reason an abundance of luminous specimens is found at that time of the year. This luminescence is simply a protective reaction; it has no direct relation to sexual life obviously, for these animals are blind. The common British *Geophilus electricus*, *G. carpophagus* and *Scolioplanes crassipes* all possess this property of phosphorescence.

Behaviour

Like insects, centipedes and millipedes breathe by means of tracheae. These are small tubes leading from a number of air-holes (spiracles) which are arranged, like the portholes of a ship, along the side of the body and the tracheae branch out into a system of even smaller tubes penetrating all the body tissues and so supplying them directly with oxygen. The carbon dioxide which is respired by the tissues is removed by the same route. The presence of a respiratory pigment in the blood has not yet been detected. *Scutigera forceps* (a long-legged southern European species which was recorded from a paper mill near Aberdeen in 1883) breathes by means of a pair of 'lungs' which have probably been evolved in correlation with its active life—it is a speedy predator and hunts for its food like a wolf-spider. (Spiders too have a compact respiratory organ, called a 'lung book' because it is composed of thin folds of respiratory tissue arranged like the leaves of a book.)

The locomotion of myriapods has long fascinated biologists, but only recently have their mechanics been analysed in detail by means of high-speed photography. Ray Lankester, who studied this matter in 1889, reached the conclusion that, if the animals had to settle the question themselves, they would not get on at all! He ended a letter to *Nature* with the following rhyme:

A Centipede was happy quite
Until a toad in fun
Said "Pray which leg moves after which?"
This raised her doubts to such a pitch,
She fell exhausted in the ditch,
Not knowing how to run.

Centipedes are nocturnal creatures, and they always live in dark and obscure places. They are very sensitive to moisture and to contact stimuli. With the exception of their eyes, which do not seem to be of much importance, their sense organs take the form of tactile hairs connected with nerve fibres; they find their prey by means of the sense of touch with which these sensitive hairs endow them.

Many species are cave-dwellers, and a few are marine. Two British species are found on the seashore, under stones and seaweed at low tide level. The smaller species, *Scolioplanes maritimus*, is fairly widespread, and has been recorded from Devon, Cornwall, Somerset, Sussex, Co. Dublin and the coast of Galway. The second species, *Hydroschendyla submarina*, on the other hand, is extremely rare, and has only been found in Jersey and Yorkshire, although it occurs in several European countries.

Millipedes not infrequently occur as guests in the nests of ants and termites. In Britain three species (*Blaniulus guttulatus*, *Proteroiulus fuscus* and *Polyxenus lagurus*) are frequently myrmecophilous. Millipedes have even been seen accompanying a column of Army Ants on the march.

In an investigation of the sensory physiology and the responses to environmental stimuli of the millipedes *Blaniulus guttulatus* and *Paradesmus* (*Orthomorpha*) *gracilis*, the writer has found that these animals react negatively to light; when they are illuminated they run actively but haphazardly in any direction until, by chance, they reach darkness. Both species are eyeless, but their

skin is sensitive to light. Those species which possess eyes, however, crawl directly *away* from a source of light, exhibiting 'negative phototaxis' to use the technical term for such response to light.

Temperature responses fall into three categories: firstly, warmth produces a general metabolic effect and the speed of locomotion tends to increase, for instance; secondly, the animals exhibit a preference for temperatures about 15° C., and tend to avoid higher and lower temperatures; thirdly, *falling* temperatures seem to stimulate to locomotory activity. Under the influence of desiccation, the animals show positive geotaxis in that they move deeper into the soil. In short, millipedes normally tend to come to rest only when they meet optimum conditions in moist surroundings (e.g. damp humus), which provide favourable contact stimuli. They do not seem to respond to odours, but they are attracted by dilute sugar solutions (containing not less than about 0·5 gramme per litre); the presence of sugar seems to be detected by sense organs (shaped like pegs and cones) on the antennae and mouthparts. (The significance of that reaction has already been discussed in connexion with millipede damage to crops.)

Mass Migration

The earliest account of migrating myriapods seems to be that of Aelion (Vol. XV) quoted in Charles Owen's *An Essay towards a Natural History of Serpents* (1752). He wrote: ". . . these little creatures [Scolopendra] make but a mean figure in the ranks of animals yet have been terrible in their exploits, particularly in driving people out of their country. Thus the people of Rhytium, a town in Crete, were constrained to leave their quarters for them." Oddly enough, this is the only record of a mass migration of centipedes, although centipedes have been seen accompanying armies of migrating millipedes. The first record of a migration of millipedes is from Transylvania in 1876.

Two years later an enormous mass of *Chromatoiulus unilineatus* actually held up a railway train in Hungary. The millipedes were so numerous that the earth was black with them; the train destroyed thousands that covered the rails, and it was finally impeded to such an extent that sand had to be strewed before the wheels could get a grip on the rails. Trains were stopped in a similar manner by *Schizophyllum sabulosum* in northern France one evening in 1900, the animals coming from a wood that came down to the railway from Lutterback. Altogether there are a dozen European records of mass migrations of millipedes; two dozen have been recorded in North America, and more than half a dozen in the Tropics.

The nocturnal movements of millipedes have been shown to be correlated with an innate daily periodicity. This daily rhythm persists in the West African *Ophistreptus* when it is kept under constant conditions for as long as 19 days, so evidently there is some kind of 'physiological clock' inside the animals by which they are able to regulate their activity. A human being would soon lose all sense of time under similar conditions. This rhythm is stimulated by rising and falling temperature, but it is not affected by light. In contrast, the daily rhythm of British species is a direct response to the normal cycle of light and darkness, but this effect is enhanced in proportion to the drop in temperature which occurs in the evening.

Reproduction

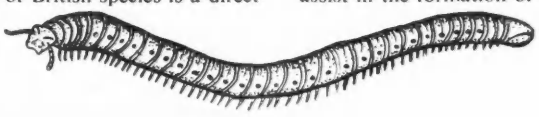
Details of reproduction have not been closely studied, but it appears that some centipedes and millipedes show a remarkable degree of parental care. In temperate regions egg-laying usually takes place during the spring and summer; though in centipedes this may follow copulation which occurred as long before as the previous autumn. In many tropical species there seems to be no regular annual breeding season. The members of the families Geophilidae and Cryptopsidae lay 15–35 eggs in a loose mass which is merely left in the soil. In the family Lithobiidae, however, the eggs are laid individually in the soil, after having been covered with earth by the female. The female Natal Forest Centipede (*Cormocephalus multispinus*) coats the eggs (which number 20–40) with a sticky secretion so that they hang together in a loose mass; she curls herself around this ball of eggs, embracing it with her legs and preventing it from touching the ground. In this species the mother remains with her young for three or four months, and does not leave them until they are old enough to fend for themselves.

In the family Symphyla the eggs are deposited singly in clefts in damp, decaying wood. Sometimes, however, the eggs are laid in clusters of about twenty, and then the female guards them; she does not, however, curl herself around them, but waits near by. If she is driven away, she soon returns and stays with the eggs until they hatch.

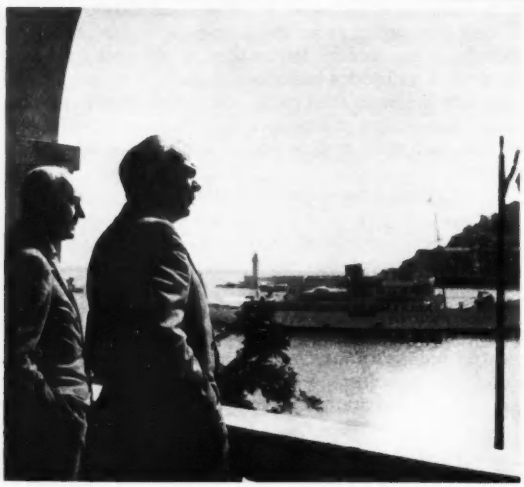
In some species of millipedes the eggs are coated with earth and excrement, and then left in crevices in the soil; in other species a nest is constructed of soil particles that have been moistened with saliva. When completed, the nest has the shape of a hollow sphere. The inside of the sphere is lined with dried excrement, and is smooth and even, whereas the outside is rough and irregular. Sometimes the female does not leave the nest immediately, but remains for several days curled around it so tightly that she is difficult to remove.

The function of all these things is apparently to protect the eggs and young from the cannibalistic proclivities of the males of the species. Before they moult, both Iulid and Polydesmid millipedes build *moulting chambers* which are essentially similar to their nests. If the moulting chamber is damaged and other millipedes enter, the helpless millipede that has just shed its skin is invariably eaten up by the invaders.

In this article I have made an attempt not only to give an account of some of the more important aspects of the biology of centipedes and millipedes, but also to indicate how recent research has shed light on the lives of these neglected creatures. For, although Buffon described them as "hideous and angry insects", centipedes for the most part are innocuous members of the community of animals, and the millipedes which eat our crops do so only in exceptional circumstances and ordinarily they probably assist in the formation of humus.

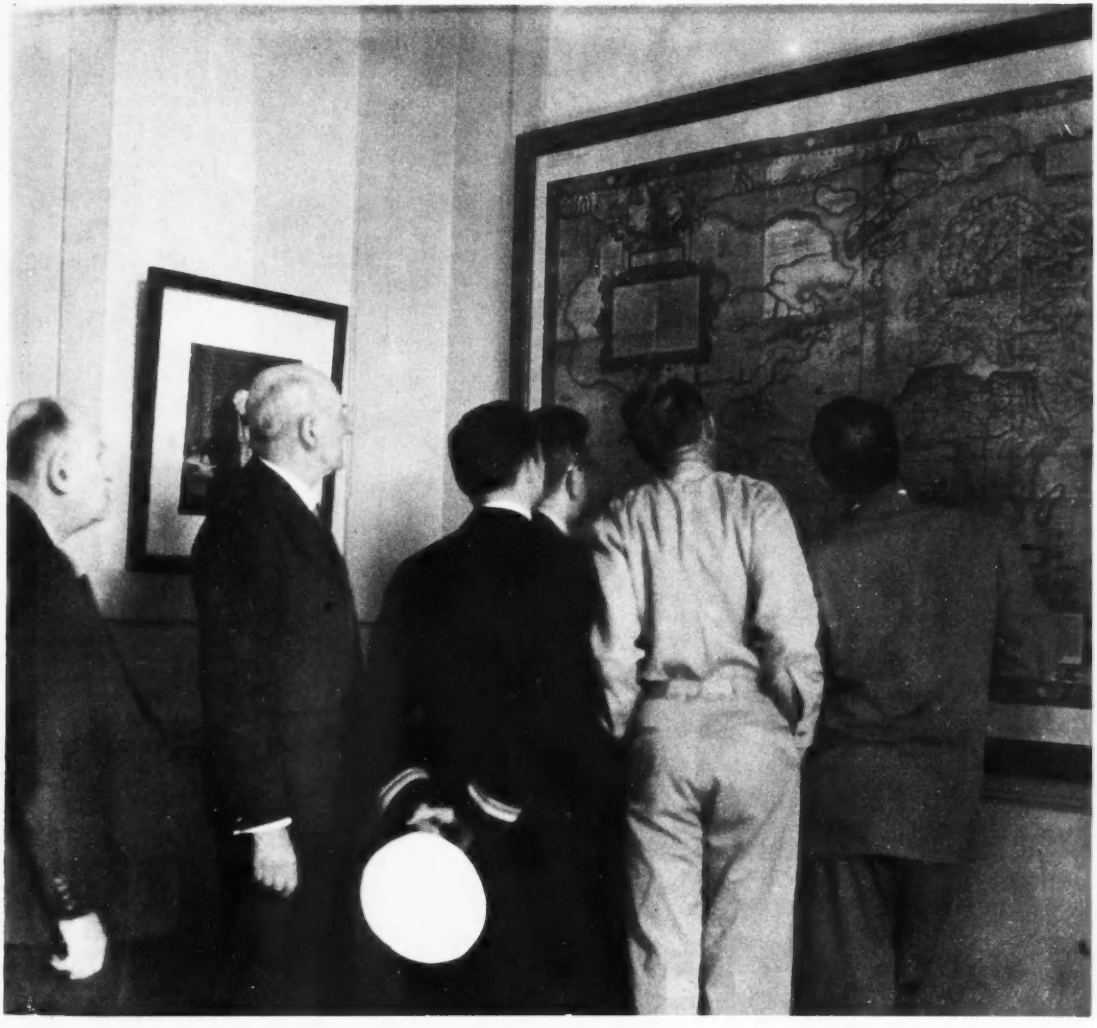


The 'spotted snake-millipede' (*Blaniulus guttulatus*).



THE INTERNATIONAL

MONTE CARLO is the home of the International Hydrographic Bureau, which co-ordinates the activities of national hydrographic offices throughout the world. Thanks to its efforts, a chart produced in Great Britain, for example, is rapidly made available to ships' masters of all nationalities. The symbols used on charts are internationally standardised. This world co-operation grew out of the International Hydrographic Conference held at London in 1919. This led to the setting up of the International Hydrographic Bureau in 1921, which is now supported by twenty-four states. The Bureau is administered by a directing committee composed of three directors, each of different nationality, and possessing long experience at sea and expert knowledge of hydrography.



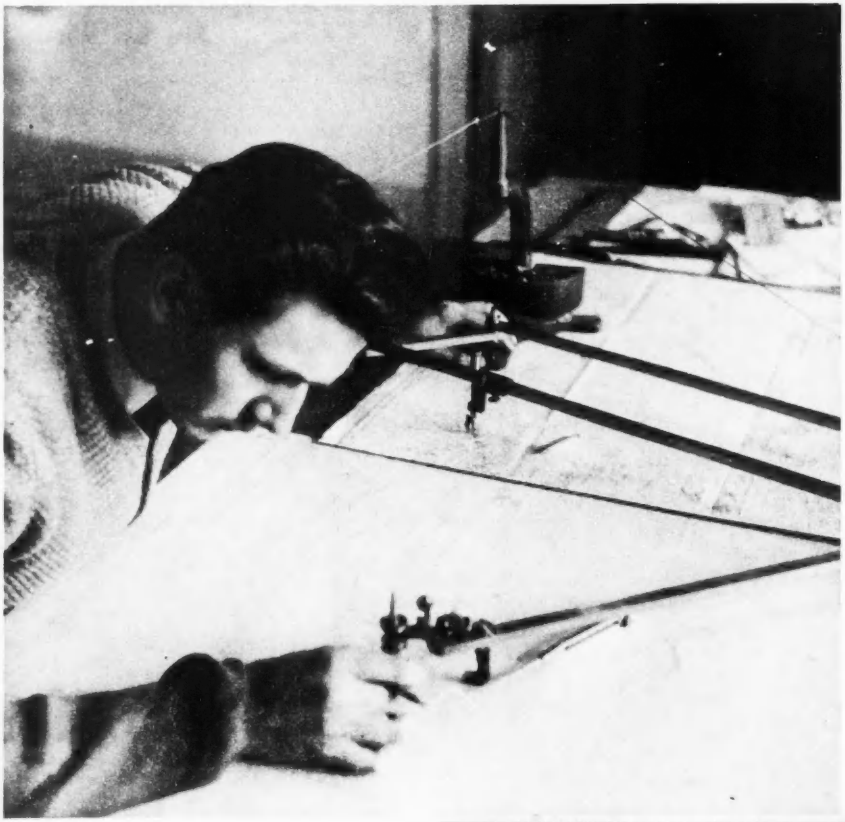
HYDROGRAPHIC BUREAU

1. The hydrographic vessels, U.S.S. *Rehoboth* and U.S.S. *San Pablo*, visit Monaco.

2. Instrumental in furthering the Bureau's aim to increase safety at sea, and in promoting its efforts towards close hydrographic co-operation between nations, are the President (Vice Admiral J. D. Nares, R.N., ret.) and Director of the Bureau (Rear-Admiral C. L. Nichols, U.S.N., ret.), here seen watching the departure of two visiting oceanographic ships.

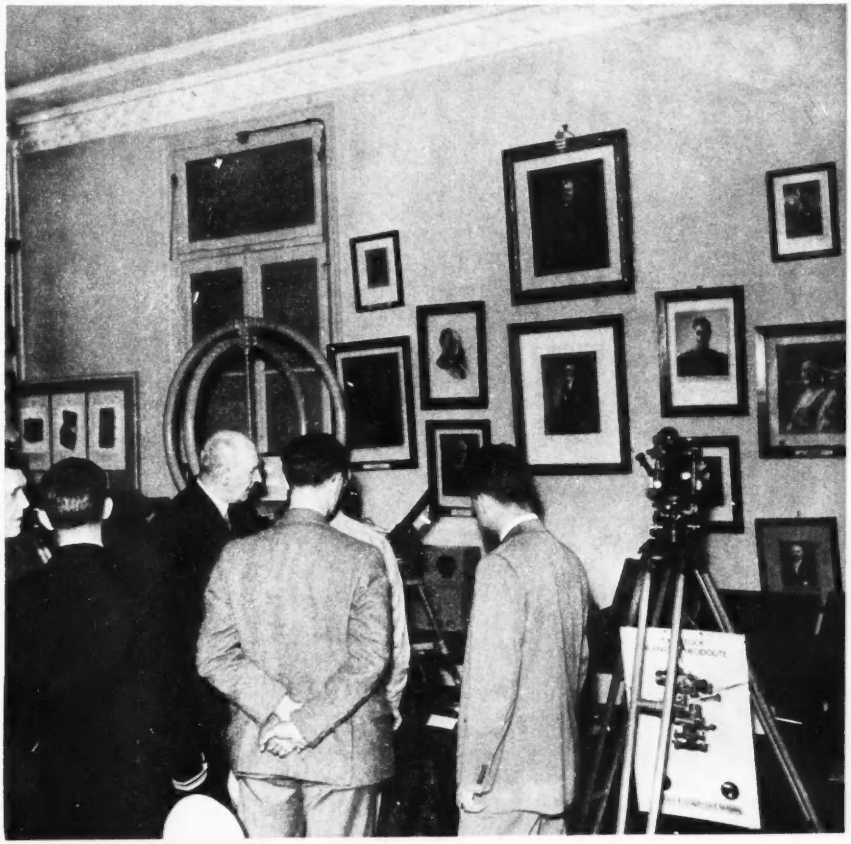
3. One of the most historic charts was that drawn up in 1569 by Mercator, the Flemish geographer, who charted a great part of the world with remarkable accuracy. A reproduction of the first edition of the Mercator-type Chart of the world is being examined.

4. The Oceanographic Bureau collects and plots ocean soundings received from national hydrographic offices throughout the world. This work is supervised by a Swiss technician, Adolphe Antognini, who is seen here with Captain H. Bencker, of the French Navy, the Bureau's Secretary General.



5. Changes in the contour of the sea-bed are constantly being reported and the hydrographic charts revised accordingly. The technician seen in this picture is an Italian, Antoine Ferrero.

6. Reproductions of early manuscript maps, including the Portolan Chart of Angelino de Nalarto (1325), from Prince Corsini's collection at Florence, are seen being examined with interest by naval officers and scientists.



7. The permanent exhibition of modern instruments used in hydrographic survey work being inspected by delegates to the recent International Hydrographic Conference.

8. Oceanographers and officers of two visiting U.S. survey ships visit the Bureau. Dr. J. N. Carruthers, the well-known British oceanographer, is seen third from left.

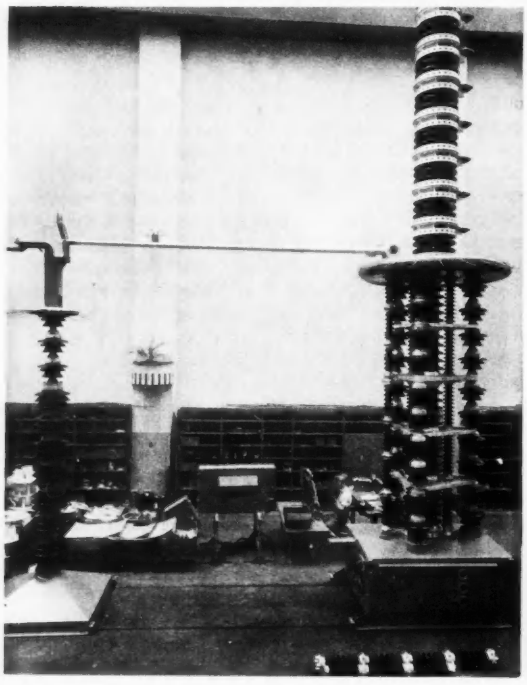


FIG. 1 (*above*).—One of the three water turbines at Harspranget.
FIG. 2 (*left*).—An air-blast circuit-breaker, 39 ft. high, for the 380,000-volt transmission line. It can cope with 8800 kilowatts.
FIG. 3 (*below*).—A specimen length of the 380,000-volt cable.

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Electric Power at 400,000 Volts

HOW SWEDEN IS TAPPING WATER POWER NEAR THE ARCTIC CIRCLE

J. H. M. SYKES

AMONG the leading countries which have harnessed their abundant supplies of water power to electric generators are Switzerland, Germany, Norway, Sweden, the U.S.A. and France. Sweden has developed over a third of her potential water power in this way, and Norway has already exploited over half.

As the best sites for hydro-electric generators are generally separated by big distances from the large centres of population and industrial production, such countries have had to devote much attention to the problems involved in the transmission of large quantities of electricity along extremely long power lines. This explains why the Swedes in particular have been pioneers in the design and use of commercial electrical apparatus employing the highest voltages yet used anywhere in the world. They have also bridged another obstacle hitherto considered insuperable by taking a power line across a sea barrier, 62½ miles wide, separating the mainland of Sweden from the island of Gotland.

Sweden is a long, narrow country, extending about a thousand miles from North to South. The vast majority of its population and its industry exists in the south. The large number of rivers has meant that electrical energy has been abundant at distances not exceptionally great from the consuming centres. Now, however, the very steep increase in the demand for electricity has meant that the whole of the most conveniently harnessable water power has been put to work, and it has become necessary to commence to utilise the large reserves existing in the far distant regions towards the Arctic Circle.

A programme of six major power stations on or near the River Luleälv has been planned. The first of these, at Harspranget, is now partially in commission. By the spring of 1952, the three 96,000 kW generators will all be at work. This first stage of development provides 300,000 kW of power, while constructional work is now under way on projects which will provide twice as much again. All the new power plants are located some 500 to 600 miles from the centres where the electricity will be used. How can this current be transported?

In electrical transmission of energy there has been a gradual increase in the voltage used. This is a natural progression; to take a water analogy, you can transport a given quantity of water over a given distance in a given time by using a low pressure with a large pipe (large volume), or by the use of high pressure with a small pipe. Translated into electrical terms, this means a low voltage and a large conductor, or a high voltage and a small conductor. A thick power cable is inordinately expensive and mechanical problems involved in supporting a very thick cable on high pylons would be insuperable if the cable had to be very long, so the obvious thing to do is to rely on high voltages. 275,000 volts has been, up to now, the highest voltage in practical use, but 389,000 volts will shortly be in use in Sweden, for the first time in the world, to transmit power from the Arctic Circle to the industrial south of the country.

As the voltage on the conductor increases, corona losses become evident. When the electric field is such that the surrounding air is stressed beyond ionisation point, a brush discharge results. This can cause a serious loss of energy: at 380,000 volts it amounts to about 5·7 kilowatts per kilometre of cable. Thus the power lost between London and Glasgow would be nearly 2,000 kilowatts—enough in itself to power a small town. There is also the question of interference with radio and television, both of which are affected when electricity is allowed to leak away in this fashion.

The design of insulation for voltages of the order of 400,000 volts presents many difficulties: for example, the glazed earthenware bushings which lead the wires into the transformers need to be over 15 feet in height, and their construction involves the use of entirely new kinds of cement. Special circuit-breakers and transformers are required, and this means long and careful research, before it can be proved that they are completely reliable at such extremely high voltages.

If these were the only difficulties in the way of increasing the length and capacity of transmission lines, it could be said that the problem is completely solved, for the Swedish engineers have already constructed a line, 600 miles long, capable of operating at 380,000 volts. But there is another and more serious limitation—the question of system stability under conditions when transient disturbances affect the network; for example, after lightning strokes and when sudden heavy load transfers occur, due perhaps to the opening of an associated circuit.

A transmission line has characteristics of resistance, inductance, and capacitance in the same way as any other piece of electrical apparatus. If an alternating voltage is applied to a network consisting of a resistance in series with an inductance, the current at the point of supply and the current at the remote end of the network will be out of phase. This is primarily due to the inductance in the circuit. When two sources of alternating current are coupled in parallel, for stable operation and sharing of the load it is necessary that a synchronising current should pass easily between them to hold them in step. Normally, in a power station, where a number of generators supply a load, they are all coupled to large busbars which offer a negligible impedance to the flow of this synchronising current. In this way, all generators, large and small, can easily keep in step under all conditions.

If two generators are connected, however, by an appreciable inductance, there will be an 'obstruction' to the passage of this synchronising current, and it will not be so easy for the generators to keep in step. When anything occurs to upset the equilibrium of the circuit, the generators fall out of step, and one or other will have to be shut down. This may cause the generator remaining in service to be

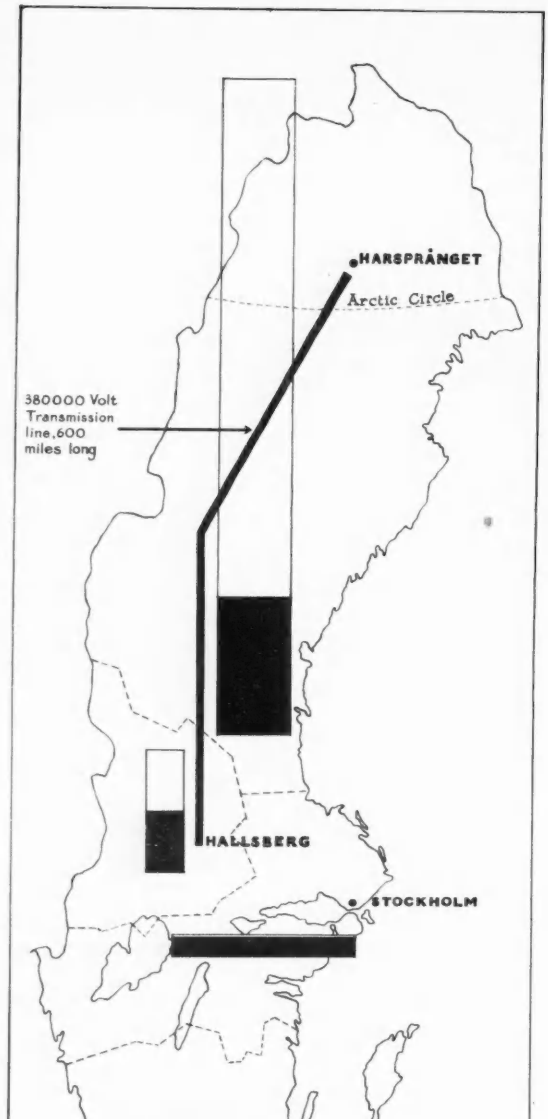

FIG. 4.—This map shows the route of the 380,000-volt cable, which will carry the current from the underground power station at Harspranget to the industrial south, a distance of 600 miles.

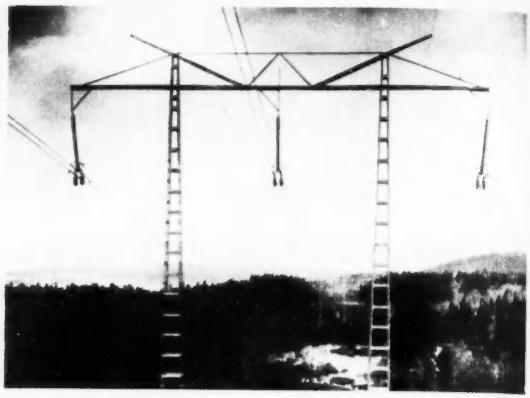

FIG. 5.—A stretch of the high voltage line, showing the two contactors used on each phase to reduce corona loss.

overloaded beyond its capacity, and the result will then be that the supply has to be totally interrupted.

This question of system stability has been the subject of special study in Sweden, where the 220,000-volt network, which has existed for a number of years, also involves lengthy power lines up to 300 miles long. To compensate for the inductance of one particular line, they installed the first example in the world of a 200,000-volt series capacitor, at Alfta, in the Stadforsen to Hallsberg line, the current actually flowing through the capacitors (previously called 'condensers') half-way along its length.

For the new 380,000-volt line, between Harspranget and Hallsberg, the solution to the corona problem has been found by employing two conductors for each phase wire. By so doing, the effective diameter is greatly increased, and this has the effect of decreasing the electrostatic stress. The result has been to reduce corona loss to 1·8 kilowatts per kilometre, and to remove simultaneously the danger of causing radio interference.

In regard to the second problem—system stability—the Swedish engineers are convinced that the 380,000-volt power line will be stable under all but the worst conditions. They anticipate that it will be entirely satisfactory in this respect, at any rate for the first stage in its life, when the power flow will be a straightforward transportation of energy in one direction. It is expected that later on additional equipment will be required when the power line is called on to do more than act as a simple energy transporter. This will occur when new lines are installed and new power plants are brought into commission in the North. The potential load would then be greater, and with a number of lines in parallel, the sudden opening of one might cause a vastly heavier power flow on the others.

As the world continues to demand more and more electricity, so it will become necessary to utilise power resources farther and farther from the centres of load. Transmission problems will become urgent. The necessity to use direct current at high voltage for sea crossings may well lead to its universal application, for it mitigates corona problems and entirely eliminates those of system stability.

Whatever happens Swedish pioneering work, in both A.C and D.C. transmission, is of the utmost importance to the world in general.

Far and Near

Night Sky in January

The Moon.—Full moon occurs on Jan. 12d 04h 42m, U.T. and new moon on Jan. 26d 22h 26m. The following conjunctions with the moon take place:

January

3d 20h	Jupiter in conjunction with the moon		Jupiter	5° S.
19d 09h	Saturn	,,	Saturn	7° N.
20d 12h	Mars	,,	Mars	7° N.
24d 07h	Venus	,,	Venus	6° N.
25d 16h	Mercury	,,	Mercury	3° N.
31d 12h	Jupiter	,,	Jupiter	5° S.

The Planets.—Mercury is a morning star, rising at 6h 20m, 6h 45m, and 7h 19m on Jan. 1, 15 and 31, respectively; towards the end of the month it is too close to the sun for favourable observation. Venus, a morning star, rises at 4h 40m, 5h 15m, and 5h 45m at the beginning, middle, and end of the month respectively; its stellar magnitude is about —3·5. Mars is a morning star, rising at 1h 15m on Jan. 1 and at 0h 35m on Jan. 31; it is easily recognised in the earlier part of the month by its position a little north of the bright star Spica (α Virginis). Jupiter is conspicuous throughout the early part of the night, setting at 23h 50m, 23h 05m, and 22h 15m at the beginning, middle, and end of the month respectively; its stellar magnitude varies between —2 and —1·8. Saturn is a morning star, rising at 0h 40m, 21h 45m, and 22h 40m, on Jan. 1, 15, and 31.

The constellation Auriga is conspicuous at this time of the year; about the latitude of London the bright star (α Aurigae Capella) in this constellation can be seen nearly overhead on Jan. 1 at 22h 20m. Allowing that it will appear 4 minutes earlier each succeeding night, towards the end of the month it will be near the zenith at 20h 20m. This information provides a simple method of identifying this star.

Capella is one of the most brilliant stars, being 170 times as luminous as the sun.

On Jan. 4 the earth makes its closest approach to the sun, its distance then being a little less than 91½ million miles.

International Centre for Chemical Microbiology

THE World Health Organisation has recognised the Instituto Superiore di Sanità in Rome as an International Research Centre for Chemical Microbiology.

The Institute has departments for research in physics, therapeutic chemistry, biochemistry, malarialogy and bacteriology. It is also the main Food and Drug Control Centre of the Italian Government.

Among new equipment recently installed is a fermentation pilot plant with fermenters up to 18,000 litres capacity and all the processing equipment required for the isolation on an industrial scale of biologically interesting substances, such as antibiotics, enzymes, and growth factors. The newly created International Centre for Chemical Microbiology will be housed in a new extension. It is under the scientific direction of the British biochemist, PROFESSOR E. B. CHAIN, F.R.S., formerly of Oxford University and joint winner of the Nobel prize for 1945 for the discovery of the chemotherapeutic effect of penicillin.

Chloroquin suppresses Malaria in Korea

EVERY United Nations soldier in Korea has been receiving each week a small white tablet for control of malaria. The 'suppressant' drug that has been issued is chloroquin, developed in the United States, and known also as 'Aralen'. Of the many malaria drugs developed during the Second World War, chloroquin has proved the most effective. Within the past few years it has checked malaria among schoolchildren in Java, and among groups in Panama and the Belgian Congo.

One small tablet of chloroquin, weighing only half a gramme, is required each week to suppress the malarial parasite that attacks through the human bloodstream. The tablet is tasteless and does not cause temporary discoloration of the skin, as does atebrin (also known as mepacrine and quinacrine). Atebrin composed the bitter yellow pill that was widely used during the Second World War.

Every United Nations soldier now receives a chloroquin tablet with his rations. He merely washes it down with water. A suppressant that is taken once a week is found to be more effectively supervised than one that must be taken every day, particularly in a combat zone.

Chloroquin does not *cure* malaria, and doctors are now experimenting with pamaquine, a new drug, to see if by using it with chloroquin a true cure for malaria can be produced.

Chloroquin was one of 14,000 compounds examined during the Second World War in the course of an all-out research drive on which the Americans spent £2 million. The chemical name of chloroquin is 7-chloro-4(4-diethylamino-1-methyl-butyl-amino)quinoline. It is a derivative of the I. G. Farben antimalarial called *sontoquin*, samples of which came into the hands of medical experts with the Allied Forces when they occupied Tunis in 1943. Sontoquin was scarcely more effective than mepacrine, so the Germans never troubled to develop it on any scale. Samples of this drug were sent back to Britain and America, where chemists determined its chemical formula. The chloroquin which was obtained by slight alteration of the molecule of sontoquin was given thorough clinical tests, and was found to possess considerable advantages over mepacrine. The upshot was that large-scale production of chloroquin was started, and according to an official report on new antimalarials issued in the middle of 1946, "if the war had continued another year chloroquin would probably have displaced mepacrine as the main antimalarial in use among the American Forces". A leader in the *British Medical Journal* (August 24, 1946) said that in its general properties "chloroquin challenges comparison with paludrine", paludrine being also known as *proguanil*.

Mothproofing with Antibiotics?

A NEW antibiotic called *netropsin*, which derives from an organism similar to that producing streptomycin, has been announced. Netropsin has already shown some indications that it may be useful against two of the most destructive of insect pests, the larvae of the common clothes moth and the black carpet beetle. However, it is too early yet to make any definite claims for it. Nevertheless, the application of an antibiotic in the field of mothproofing appears to break new ground, and further developments will be closely watched. From the chemical standpoint, netropsin differs from other antibiotics in its high nitrogen content; its formula is probably $C_{32}H_{48}N_{18}O_4$.

A New Rat-repellant

THE antibiotic called *actidione* proves to be highly repellant to laboratory rats and to reduce significantly gnawing attacks upon treated paperboards. This is disclosed by Robert Traub, James B. DeWitt, Jack F. Welch and Doris Newman in a paper published in the *Journal of the American Pharmaceutical Association*, Scientific Edition, 39, 552 (1950). Rats refused to accept food or water containing this material even under conditions of acute starvation and died of starvation and thirst rather than accept water containing 1·0 milligram of actidione per litre. The compound is highly toxic to rats; the minimum lethal dose by oral administration is approximately 1 milligram per kilogram body weight. Paperboard treated with the compound resisted gnawing attacks by specially conditioned rats for periods of 200 hours, although similar untreated boards were pierced in 30–60 minutes.

A Film about Fisheries Research

WITHIN the shadow of the Torry Light at Aberdeen stands the Scottish Marine Laboratory, established in 1899, whose scientists devote their time and skill both ashore and afloat to discovering all the facts relating to the life-history and habits of the more important food fishes. Included in the staff of the laboratory is a team of hydrographers and chemists who study water movements and make analyses of nutrient and other salts present in the water. During the course of a year thousands of drift bottles are liberated in the waters north and west of Scotland, and from the records of their strandings a comprehensive picture of the

(Left.) *Prof. James Riddick Partington, famous for his chemistry lectures and textbooks, especially "A Textbook on Inorganic Chemistry", has just retired, relinquishing his chair at Queen Mary College, London University, to Prof. M. J. S. Dewar.*

(Right.) *Dr. Max Theiler, 1951 Nobel prize-winner in Medicine. The attenuated strain of yellow-fever virus found by him and the late Dr. W. D. M. Lloyd has been used to immunise over forty million people. A South African, he qualified as a doctor at St. Thomas's Hospital, London.*

current systems in the North Sea and adjacent waters is built up. Experts on plankton are included among the laboratory's biologists and their task is to study the minute floating vegetable and animal life which, after the nutrient salts, provide the basic food for all aquatic animals. Four research ships attached to the Laboratory are at sea throughout the year with the exception of their annual refitting period. The investigation area extends from the Dogger Bank throughout the northern North Sea to the Faroe Islands and the Oceanic Banks of the East Atlantic, with occasional excursions to Icelandic waters. The chief work of these research ships is concerned with sampling the fish populations, and studying their environments and observing the effects of intensive fishing on fish stocks.

The *Scotia*, the ship featured in the recent COI film, "Explorers of the Depths", is a converted Admiralty Isles class trawler built during the Second World War when it bore the name *Fluellen*. When engaged on investigation the *Scotia* carries four or five scientists in addition to her crew. The ship's equipment includes echo-sounding apparatus, trawls for sampling fish population, silk cone-shaped nets for the collection of plankton samples, dredges and grabs for sampling invertebrate bottom fauna, and hydrographical equipment for sampling the water and recording temperature at all depths. The demand for fish is high and there must be a rational exploitation of the resources of the sea by all countries interested in fisheries, thus close co-operation exists between all European scientists whose work is co-ordinated through the International Council for the Exploration of the Sea with its headquarters at Charlottenlund, near Copenhagen.

In addition to the *Scotia*, another research ship the *Explorer* is engaged in deep-sea work, a smaller vessel the *Clupea* devotes herself entirely to the study of the herring, whilst the fourth member of the quartet, the *Kathleen*, is engaged in inshore investigation in bays and estuaries. The haddock, herring, whiting, lemon dab, plaice halibut and lobster all come in for special investigation at Aberdeen, whilst methods of fishing and fishing gear are also under constant review. The classification of the many samples of plankton, the determination of the location and growth of the various varieties of fish and the answer to such questions as to how many fish can be taken without depleting stocks, and where they may be more plentifully found, these are just a few of the problems with which the scientists of the Marine Laboratory concern themselves.

A laboratory associated with that at Aberdeen has been established at Pitlochry, Perthshire, and this station is engaged on research into brown trout in collaboration with the North of Scotland Hydro-Electric Board. In England the Ministry of Agriculture and Fisheries has a laboratory at Lowestoft similar to that at Aberdeen. As a Government establishment the Director and staff of the Aberdeen laboratory act as advisers to the Secretary of State for Scotland and the Fisheries Administration of the Scottish Home Department on matters affecting the commercial fisheries, many of the regulations brought in by the Administration are introduced as a result of the research work undertaken by the laboratory.

The film "Explorers of the Depths" tells the fascinating story of the normal work and routine of a research ship, and indicates one of the greatest problems facing the fishing industry today—namely over-fishing or the removal from the North Sea fishing grounds of fish at too high a rate. With the continuing development in the use and efficiency of underwater photography (brilliant examples of which are contained in this film), there is an increasing opportunity for the study of the behaviour of submarine animal life in its natural surroundings, and also for a comprehensive survey of the behaviour of fishing gear in operation. "Explorers of the Depths" is a short film, a mere ten minutes, but it relates a story on the successful conclusion of which depends the future of our fishing industry and the solution of many of our food problems.

Manchester University's Automatic Digital Computer

MANCHESTER University's Automatic Digital Computer is believed to be the most versatile machine so far constructed anywhere in the world.

These machines are all called 'digital' computers because they work with the ordinary digits of conventional arithmetic, and they can use as many figures as are needed for the particular computation they are doing at the moment, so that there is no limit to the precision with which they can work.

All machines of this type can do *three* things:

(1) They can perform all the operations of arithmetic exceedingly fast. (For example, a girl with a standard desk calculating machine can do about 600 multiplications of pairs of ten-digit decimal numbers in an average working day. The Ferranti machine will do about the same amount of work in two seconds. It can, in fact, do far more arithmetic in a day than the average man can do in a lifetime without the same likelihood of error.

(2) They can remember a great many numbers, and also the long and elaborate series of instructions which they have to obey in order to perform a complicated calculation automatically. It is believed that this new machine has a bigger memory than any other in the world. It can remember 16,000 twelve-digit numbers, and can recall any one of them within one-thirtieth of a second.

(3) They can make decisions; that is to say, a machine can decide at any stage in a calculation which of two or more contingencies has occurred, and determine its future course of operations accordingly. The two alternative courses of action must, of course, have been prescribed by the mathematician who is working the machine, but nevertheless the machine decides between them in the light of the results which it has achieved so far. In other words, it can arrive at results by playing a sort of mathematical version of the game of "Twenty Questions".

The possibility of making such a machine was first suggested over a century ago by Charles Babbage, then Lucasian Professor of Mathematics at Cambridge. He was unable to complete it owing to lack of financial support and because of the inadequate techniques available to him, but, to judge from the accounts of his work which were written by Lady Lovelace (the daughter of the poet Byron), it is clear that he had a more profound understanding of the principles and possible applications of these machines than anyone else achieved until a few years ago. It is interesting to note that it is hoped to demonstrate soon on the Manchester machine the solution of a problem which had been studied and solved by Lady Lovelace before the Great Exhibition of 1851.

The first modern machine was made by the International Business Machine Company in collaboration with Professor Aiken of Harvard University. This machine was relatively slow as it used relays rather like those used in a telephone exchange; a second machine, built at Pennsylvania University, made use of valves and was, in consequence, very much faster.

The new Ferranti machine at Manchester is in detail quite different from those two machines. It is built in two bays, each 16 feet long, 8 feet high and 4 feet wide. It contains 3500 valves, 12 cathode-ray tube stores—these were the invention of Professor F. C. Williams and Dr. Kilburn of Manchester University—and a magnetic drum storing 16,000 twelve-digit numbers. Problems are put into the machine via teleprinter tape at the rate of 200 decimal digits per second, and the machine prints its results on a standard teleprinter.

The machine consumes 27 kilowatts of power and is kept cool by a stream of air. It contains 2500 condensers, about 15,000 resistances, 100,000 soldered joints and about 6 miles of wire. It took approximately eighteen months to build, and Ferranti Ltd. expect to complete a second machine before the end of this year. (They have already started work on a third, and plan to build a whole series of computers.)

It is felt that there is a great future for machines of this type as they can perform long and elaborate computations so swiftly. For instance, in atomic physics they are invaluable for making calculations of nuclear and atomic structure and the theory of plutonium-producing piles.

Enzymes v. Deep Infections

INTENSIVE research and development carried out by the Lederle Laboratories Division of the American Cyanamid Company has resulted in 'Varidase', a new human biological. This new drug will liquefy clotted blood, thick pus, and dead tissue in deep-seated infected areas without harm to living tissue, dissolving the debris which can then be drained off with little or no surgery being necessary.

This material is known by the initials *SK-SD*. It has produced dramatic results in a wide variety of troubles ranging from heart inflammations, lung infections, tubercular meningitis, middle ear infections, gunshot wounds and bone infections, as well as chronic sinusitis.

It has been known for several years that certain streptococci, grown under suitable conditions, produce small quantities of two enzymes which dissolve pus and fibrin. But until Lederle took up this research, no practical method had been devised to obtain enough of the enzymes to make clinical research possible.

These two enzyme products—known by the names of streptokinase and streptodornase, hence *SK-SD*—provide the surgeon with a revolutionary new tool which makes for speedy healing in inaccessible parts of the body. Many infections of the extremities result in gangrene, amputation, and even death. 'Varidase' will remove the dead material immediately, stimulating the healing return of the blood supply and making it easier for a powerful antibiotic such as aureomycin to prevent further infection while the body repairs the damage, it is claimed. In deep-seated chest infections 'Varidase' is changing the whole treatment with a promise of rapid recovery. When injected into the infected area, 'Varidase' brings about chemical changes which liquefy accumulations of fibrin and pus. This waste material, which obstructs natural healing, can then be withdrawn from the body with a needle or by minor surgery. Once this dead material is removed, the body's natural defences, the white blood-cells, and an antibiotic, such as aureomycin, can attack the infection directly and clear it up. Blood clots which appear in the joints, the chest or other body cavities can be quickly liquefied by 'Varidase'.

The Bookshelf

The Electric Current. By P. Dunsheath. (London, G. Bell, 1951, 211 pp., 18*s*. 6*d*.)

THE CHILDREN'S LECTURES delivered each Christmas at the Royal Institution are world-famous, and several sets of these lectures which have been printed have become best-sellers. This book contains the six lectures, which Dr. P. Dunsheath presented to his "juvenile auditory" during the Christmas holidays of 1949–50, and the text is illustrated with numerous photographs and line drawings. It should be purchased by all public libraries. A copy ought to go into every school library, while parents will not be wasting their money if they buy it as a present for their young sons, who are interested in scientific things and who have just started or are about to start studying science at school.

Chemistry of Organic Compounds. By Carl R. Noller. (Philadelphia & London, W. B. Saunders, 1951, 884 pp., 35*s*.)

THIS book by Professor Noller of Stanford University is designed for university students. A good idea of the comprehensive coverage the volume provides is conveyed by the fact that the index takes up 47 pages, so that it makes a first-class reference book as well as a first-class textbook. The author has taken pains to explain the modern theories of structure so that the student can see the rhyme and reason which has changed organic chemistry from a mere assemblage of poorly correlated facts into a subject which holds today a greater attraction for the elementary student than does inorganic chemistry: the basic patterns of molecular structure exhibited by the many and various groups of organic compounds are very clearly depicted, and Prof. Noller uses the molecular orbital treatment developed by Hund, Mulliken, etc., to give a physical picture which enables the reader to understand the source of bond energies, the nature of multiple bonds and resonance. The student can then proceed to like this molecular orbital picture of bonding and resonance with the atomic orbital symbolism developed by Pauling and others.

The technology of the organic chemical industry is treated very well, and the author gives up-to-date information about modern productive methods in use by this ever-expanding industry.

A final point for which the author deserves praise: he has gone to great trouble to give 'potted' biographies of the great organic chemists, and this helps the students to see the development of organic chemistry as one of the great achievements of the human mind, and to realise that it has old and healthy roots which delve deep into such old technics as pharmacology and the traditional fermentation industries. It is essential for modern man to appreciate just how deep are the roots which feed his civilisation, for such an appreciation gives a sense of being part of the main stream of history instead of just seeming to be an adventitious expression of animal energy that has arisen in an uncomfortable and anxious world. One does not usually expect a text-book of organic chemistry to provide any kind of basis for a philosophy of life, and Prof. Noller deserves something more than congratulations because he has succeeded in doing just that.

Collecting and Breeding Butterflies. By Brian Worthington-Stuart, F.R.E.S. (London, Warne, 1951, 190 pp., 10*s*. 6*d*.)

THE "Wayside and Woodland Series" has established a unique niche for itself in the naturalist's library, and Richard South's *The Butterflies of the British Isles* in this series is used by nearly everyone interested in the native species of Lepidoptera. Like W. J. Stokoe's complementary book, *The Caterpillars of the British Isles*, this new "Wayside and Woodland" volume is extremely useful and should prove just as popular. It provides comprehensive

details of the equipment needed and also instructions for the making of nets, cages, etc. There are special sections on capturing, killing, setting and recording: there are also suggestions for the breeder on rearing species in captivity. It is illustrated with a colour frontispiece (showing a suggested lay-out for mounting a number of related butterflies) and abundant clear line drawings.

Introduction to Mycology. By J. A. Macdonald. (London, Butterworth's Scientific Publications, 1951, 177 pp., 163 t.f., 15*s*.)

THIS book is intended to supply a straight guide to an understanding of mycology by reference to a limited number of examples. I do not feel that the book will give the student a well-rounded introduction to the subject, or that it will stimulate him to continue with the study of the fungi, for it lacks attraction in style and in illustration. The style is rough, the information often insufficient. Had some of the space which is taken up in discussion of the difficult questions of relationships been used to give more information about the fungi, the value of the book would have been increased.

The author has limited his references to recent publications, and in this he may well be wise; but an inexperienced student will need guidance if he is to pass from this book, with comfort and profit, to the wide reading of older work which forms an important part in the training of a mycologist.

I cannot praise the illustrations. Some are neither pictures nor diagrams, and some may reasonably cause discontent in the minds of the authors from whose work they have been adapted. The student may not find it easy to match the figures against the specimens he examines, nor will those figures lead the student into habits of accurate observation or of faithful drawing.

The book can be recommended to students who need an aid to revision, after they have completed a course of lectures accompanied by thorough practical work. It is likely to disappoint a reader who has not already a working knowledge of the subject.

B. BARNES.

Selective Toxicity. By Adrien Albert. (London, Methuen, New York, John Wiley, 1951, 228 pp., 7*s*. 6*d*.)

THIS is the second volume in the new series of monographs published by Methuen, which deals with biochemical topics and is edited by Prof. R. A. Peters of Oxford and Prof. F. G. Young of Cambridge.

The great success of chemotherapeutic agents, such as the sulpha drugs, the antibiotics, and the selective weed-killers and insecticides, has focused attention on the phenomena involved in selective toxicity. This book, based on a course of lectures delivered at London's University College in 1949 by Prof. Albert of the Australian National University, is concerned with the physical and chemical means by which selective poisons affect some kinds of cells and not others. As the author says, selective toxicity is now ripe for the discovery of basic principles which will give depth to our understanding of what has tended to be a branch of technology rather than of science. The formulation of such principles requires the bridging of the gap separating the diverse disciplines of biology and chemistry, and this book represents a useful sketch of the type of bridge that is needed. (Perhaps the analogy could be made closer by saying that the volume represents a rope bridge thrown across the gap, and will do valuable service until such time as a stouter and more nearly perfect bridge of theory can be built.)

Since the day when Ehrlich coined the word *chemotherapy* and started the ball rolling with his discovery of Trypan red, Atoxyl and Salvarsan, this branch of technology has attracted thousands of recruits, and a number of significant correlations between selective toxicity on the one hand and the different chemical and physical properties on the other have been detected. Ehrlich himself was fully aware of the crying need to discover *general laws* governing chemotherapy, but it is a remarkable fact that the technological advances he and others who came after him made owed very little to theory. The story of penicillin is typical rather than exceptional, and is the supreme example of an accidental discovery which was thoroughly exploited by men, in particular Florey and Chain, who were prepared to follow up the lucky accident which revealed the existence of this potent antibiotic.

One of the first basic principles to be revealed was, the chemical nature of the union between a drug and a parasite; this occurred when Voegtlin demonstrated that the toxic action of arsenicals was due to the formation of arsenic/sulphur bonds —the sulphur being present in thiol groups in the parasites.

The modern period (1935 onwards) opened with Domagk's discovery of Prontosil, first of the sulpha drugs. Perhaps even more important was the French work which showed how the inactivity exhibited by Prontosil towards bacteria *in vitro* could be overcome by adding a reducing agent. This put the investigation of new sulpha drugs on a more scientific basis, and there is little doubt that it speeded the development of a whole new armoury of drugs including, among its most effective weapons, sulphapyridine, sulphadiazine and sulphaguanidine.

Filde's work on *p*-animodenzoic acid (coupled with his suggestion that there was a similarity between the blocking of an enzyme by a foreign substance, and the action of a drug on a parasite) inspired a more rational approach to the whole subject. To quote Prof. Albert, the lock-and-key relationship between enzymes and their metabolites leads to the picture of a chemotherapeutic agent as "a key that fits the lock [but] only well enough to jam it".

The biochemical aspects of the antibiotics are fascinating, but they are not easy to study and it is not easy to find general laws controlling their mode of action. For instance, on the hypothesis that organisms secrete substances like penicillin as a defence mechanism against their natural enemies brings one up against the blank wall of fact: one would expect that, if penicillin gave *Penicillium notatum* some advantage in the struggle for survival, then the few strains of this mould which yield penicillin would be the most successful, and therefore the commonest strains—but, in fact, they are the most uncommon! This is just one of the fascinating paradoxes of selective toxicity, on a par with the fact that the potency of a series of drugs graded by tests on laboratory animals bears no simple or direct relationship to the potency of those drugs when tested on human patients.

Prof. Albert also gives a brief survey of work done with selective poisons in cancer research. Some success has been scored here; e.g. with the nitrogen-mustards. This work ties up with the researches of cytologists on mitotic poisons, i.e., chemicals which upset the process of nuclear division. Here the synthesis of nucleic acid is being studied in connexion with the possibility that an agent may be found that will affect this synthesis in such a way that the growth of cancer tissue can be stopped. Aminopterin is interesting in this connexion, but unfortunately the margin between the *effective* dose and the *toxic* dose is too narrow to justify its use. Guanozolo is more promising, for in mice at least it is far less toxic than aminopterin. The relation between chemical structure and action on tumours calls for much more investigation; at present the mode of action of the *tumour-producing* chemicals is better understood than that of the *tumour-arresting* chemicals.

The whole field is a powerful challenge to human ingenuity, and very rightly Prof. Albert ends his book with a plea for the establishing of a research institution devoted exclusively to the study of the basic principles of selective toxicity. Such an institution is indeed needed if the right kinds of talent are to be assembled so that they may set about cracking what is undoubtedly a very tough problem.

Bees: Their Vision, Chemical Senses and Languages. By Karl von Frisch. (New York; Cornell University Press, London; Geoffrey Cumberlege, Oxford University Press, 1950, 119 pp., 18*s*.)

IT is quite fair to say that the results which von Frisch obtained in his classic experiments on the behaviour of bees, in particular those concerned with bee dances, are incredible. They invariably arouse immediate scepticism at the first encounter, and von Frisch himself has said that "no competent scientist ought to believe these things on first hearing".

But von Frisch's experiments are truly conclusive, for he cunningly designed them so that only one clear-cut conclusion could be drawn from the results of each experiment. His experiments have been repeated by others, who have obtained the same results. For example, Dr. W. H. Thorpe of Cambridge University testifies that he was able to perform with von Frisch and "for myself . . . 'repeats' of certain of the most crucial experiments. This memorable

experience . . . convinced me of the soundness of the conclusions as a whole." Prof. Donald R. Griffin of Cornell University (well known to our readers for his classic work on the ultrasonic 'radar' system in bats) contributes a foreword to this book in which he admits that he had doubts about von Frisch's experiments, but that these were dispelled in the course of a few weeks' work with a colony of bees which led him "to the same degree of conviction as that which Thorpe reports".

The dance language of bees, which enables the insect to communicate to others the distance and direction from the hive of abundant sources of nectar, is now established beyond serious question. Von Frisch has spent forty years on his studies of bee behaviour, and this book is a definitive account of all that work. It is so beautifully, simply, concisely written that it should be understood by anyone interested in the subject; only the appendix dealing with the bees' orientation by polarised sky light and including a description of the octagonal artificial bee eye which von Frisch made out of eight triangles of 'Polaroid', will present any difficulties, but it must be added that this section provides the most lucid and simple account of the polarisation effect so far published.

The book should inspire many people to test von Frisch's explanations of bee behaviour for themselves for as Prof. Griffin has said, "now that his insight has made order where there seemed to be utter chaos, anyone with a little patience and a hive of bees can test the principal conclusions for himself".

Fluorine. By R. N. Haszeldine and A. G. Sharpe. (London, Methuen, 1951; pp. 153, 8*s*. 6*d*.)

THE new importance of fluorine and its compounds makes the issue of this book timely. The emphasis is on the fundamental chemistry of fluorine, but the industrial aspects (which were dealt with in DISCOVERY, Feb. 1950) are not neglected. The use of hydrofluoric acid in alkylation, boron trifluoride in polymerisation, new refrigerants and volatile uranium compounds all find their place.

F. E. W.

Radiation Monitoring in Atomic Defence. By D. E. Gray and J. H. Martens. (New York, Van Nostrand; London, Macmillan, 1951; 122 pp., 15*s*.)

IT is recognised by civil and military defence authorities that most of the radiation monitoring necessary in the event of atomic warfare cannot be carried out by highly trained scientific personnel. This volume is intended to supply all the information that is required to enable monitors with limited or no technical training to perform their duties adequately. It fulfils this purpose admirably.

Part I of the book is devoted to a brief and simple account of atomic energy, nuclear radiations and the hazards associated with atomic bombs.

Part II gives a comprehensive survey of the measuring equipment which comprises the AEC monitoring kit designed for defence personnel. Separate chapters are devoted to the Geiger Counter Survey Meter, Ionisation Chamber Survey Meter, the Proportional Alpha Counter, Pocket Chambers and Dosimeters and Film Badge Dosimeters. The function, calibration, use, likely faults and simple tests of these instruments are described in the simplest possible manner. Although these descriptions are confined to standard American equipment the main features apply also to standard monitoring equipment in use in this country.

This book will be easily understood by readers with only a very limited technical knowledge and will be of invaluable help to those who wish to concern themselves with this aspect of atomic defence.

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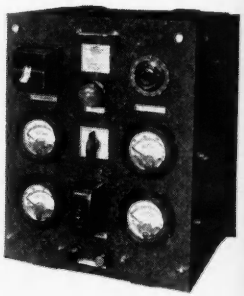

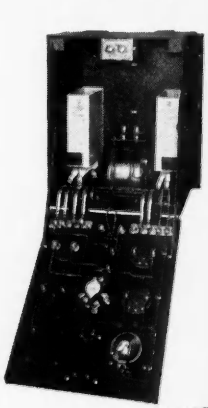

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